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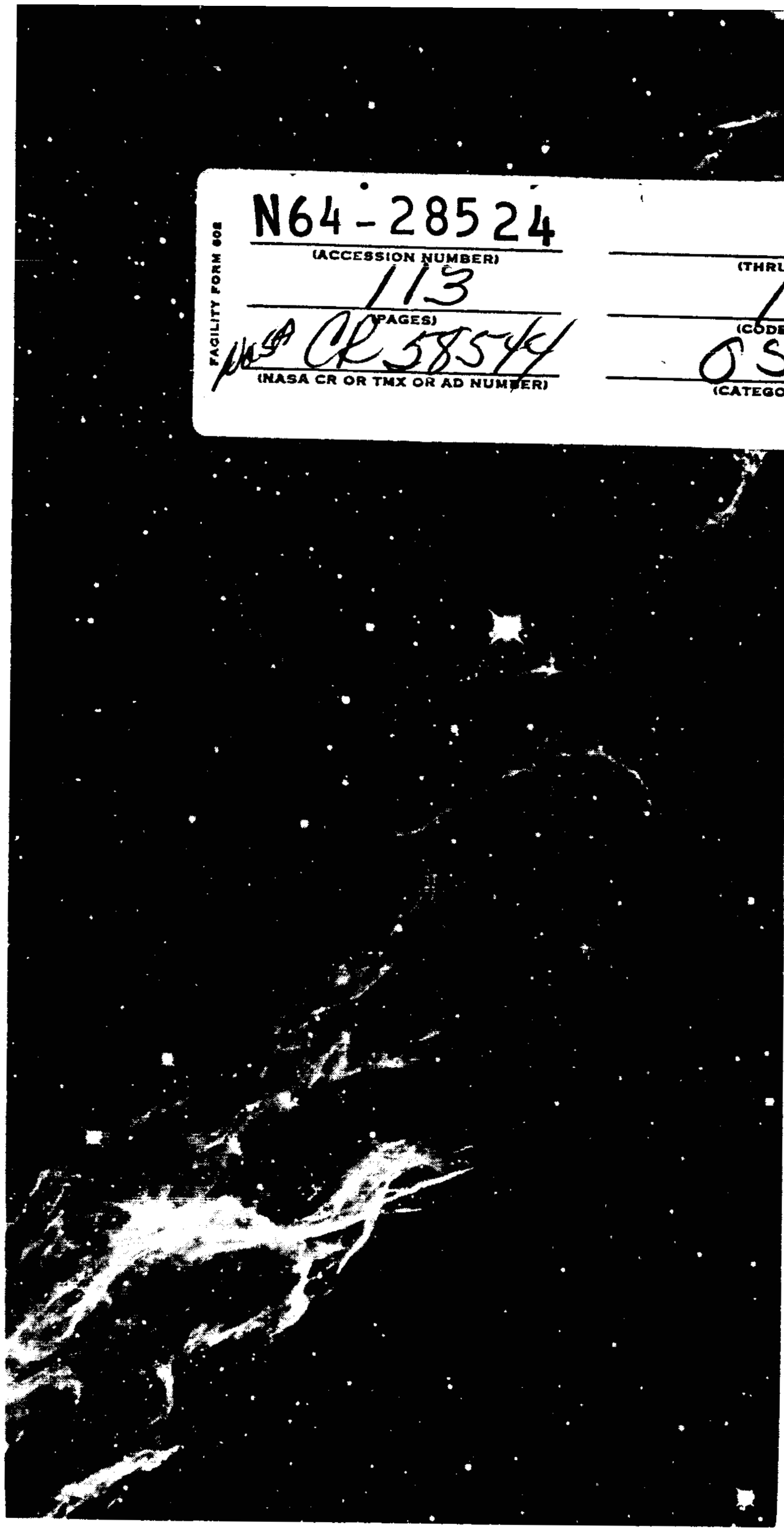

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A COMPENDIUM OF DATA ON SOME PERIODIC COMETS

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Report No. P-9

A COMPENDIUM OF DATA ON SOME PERIODIC COMETS

by

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ABSTRACT

A COMPENDIUM OF DATA ON SOME PERIODIC COMETS

The data on some periodic comets is presented to provide ordered information for the scientist interested in the exploration of the solar system. Thus it is concerned only with those periodic comets which will have perihelion passages within the next twenty five years and for which data has been obtained from at least two previous apparitions. Furthermore it forms part of a four volume comet mission analysis performed by the Astro Sciences Center of IIT Research Institute, the other volumes dealing with the scientific objectives of comet missions, sighting and trajectory analyses for comet intercept, and a comet mission and payload study.

It is not possible to summarize the properties of the comets detailed in the data sheets except perhaps to say that all short period comets are relatively inactive and unspectacular, and in general they are faint. The exception to this generalization is Halley's comet which is bright and large, and emits both gas and dust particles quite profusely. Not very much physical data is available, particularly spectroscopic data, on the periodic comets considered but it is this limited information which must

be used in selecting the first comet missions. The data which is provided is classified as follows:

1. Historical data stating the year of discovery, the number of times observed, and an indication of the likelihood of perturbation.
2. Brightness stating the most recent brightness equation for computing the comet's expected magnitude within the visible part of its orbit. The minimum brightness usually observed photographically is 20 mag.
3. Orbital elements with the year of perihelion when they were last confirmed.
4. Physical appearance stating the appearance of the nucleus, coma and tail on recent apparitions.
5. Recent recoveries giving pertinent parameters on at least two previous apparitions both at the time of recovery and at perihelion.
6. General comments on the visibility and knowledge of the comet and, where applicable, the expected quality of future apparitions.
7. Polar charts showing the approximate orbit of the comet projected onto the ecliptic plane and the relative positions of the Earth on past and future perihelion dates.

In order to give the reader a gross indication of the basic orbital and physical properties of short period comets, a table of mean values of comet parameters is included. This is supported by listings of all the comets considered in terms of period, semi-major axis, inclination, eccentricity, perihelion distance and perihelion date.

Finally a table is included which lists those comets which are recommended for further consideration for intercept missions in the period 1964 to 1986.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page No.

Report No. P-9

A COMPENDIUM OF DATA ON SOME PERIODIC COMETS

1. INTRODUCTION

This compendium presents data on the individual period comets which have been considered by the Astro Sciences Center of IIT Research Institute in a study of comet missions. An earlier report (Roberts 1963) presents the scientific objectives of comet missions and impending reports will contain trajectory and sighting analyses for comet missions and a comet mission and payload study. The initial sections of this compendium show how the data sheets and the polar charts can be used to derive a first selection of the comets most suitable for space missions. The selected comets are listed in Table 8.

Comets were definitely established as solar system objects, outside the Earth's atmosphere, by Tycho Brahe in 1577 and the first comet orbits were determined by Halley in 1705 using Newton's gravitational theories. Since then a great deal of orbital data has been obtained and is distributed throughout the astronomical literature. The standard catalogues of comet orbits are those of Galle (1894), Crommelin (1925, 1932) and more recently Porter (1961).

The physical properties of comets are less well documented although subjective descriptions of the more spectacular apparitions go back as far as 467 B.C. In recent years the Astronomical Journal and the Publications of the Astronomical Society of the Pacific have published continuing reports of comet observations. The comets most frequently observed are Encke, because of its short period, and the "annual" comets Oterma and Schwassmann-Wachmann 1 which are visible each year because of their low eccentricity.

This compendium brings together orbital and physical data on some of the periodic comets of interest for space missions. The comets included have been selected on the basis (a) that they will pass through perihelion at least once within the next 25 years and (b) that they have been observed during at least two recent apparitions. Those comets excluded by (a) need not be considered at this time for comet intercept missions and condition (b) gives reasonable assurance that the predicted return of the comets will actually take place. It is very probable that during the next 25 years about 10 or more interesting and bright "new" comets will be discovered and some of them a year or more before perihelion. The data for many of the included comets is sparse but represents the best current knowledge. In general periodic comets are faint and unspectacular compared to the bright and active "new" comets whose appearances unfortunately cannot be predicted. Furthermore each comet must be considered individually in terms of its size, shape, constitution and brightness although successive apparitions of an individual comet usually show marked similarities.

Periodic comets have significant eccentricities and generally pass beyond the orbit of Jupiter. Due to this and the mass loss during each solar passage, comets continuously suffer small perturbations and occasionally when they approach very near a planet they will suffer a very large perturbation. Therefore it is not possible to predict accurately the future orbit of a comet and in all cases it will probably be necessary to recover* the comet and check its orbit before a spacecraft is launched.

The data, or lack of data, presented for the individual comets is important in assessing the value of a scientific mission to a particular comet. The data makes it possible to select comets of scientific interest and in conjunction with the polar charts, which show the relative positions of the comet and the Earth at each perihelion, to estimate qualitatively how long before a particular perihelion the comet may be recovered, and whether it will be possible to observe it at perihelion.

2. COMETARY DATA

The data presented for each comet has been gleaned from a wide range of the astronomical and astrophysical literature. In most cases the data is limited to a description of the comet as it appears on a photographic plate and not even the simplest spectrometric analysis is available for the majority of the periodic comets considered. This is because periodic comets are

* Recovery is the first sighting on each passage of the comet.

in general faint and inactive. The major exception to this is Halley's comet which is expected to pass through perihelion in 1986 and which was reported on very fully by Bobrovnikoff (1931) for its last apparition in 1910. Halley's is the periodic comet of outstanding scientific interest of those included in the compendium.

In using the data sheets there are qualifications in the interpretation of the data which should be borne in mind particularly when predicting the comet's position or appearance for future passages. The qualifications are dealt with in the following subsections discussing the various aspects of the data sheet presentation.

2.1 Historical Data and Comet Designation

The year in which the comet was discovered is given in this section together with the number of times it has been observed. An indication of large perturbations of the comet is also given. Comets are referred to by name, usually the name of the discoverer, or independent discoverers, and this is usually adequate identification, for example periodic comet Arend. However they also receive an official designation in Roman numerals representing the chronological order of perihelion passage for that year. Thus Arend is officially designated 1951X (i.e., the tenth observed comet to pass its perihelion in 1951) and also as 1959V. Further a temporary alphabetical designation is given to a comet when it is discovered or recovered representing the order in which it was seen in a given year. Thus Arend has also been temporarily designated 1951j and 1959c. The temporary designation is superceded by the official designation within a few years of the appearance of the comet.

2.2 Brightness

Comets exhibit a greater range of brightness than any other class of celestial object except possibly novae or supernovae. The brightest comets have even been visible in daylight. At the other extreme, observational limitations are imposed by the telescopes and photographic techniques used, the lower limit being about magnitude 20. Bright comets are rare and the number visible to the naked eye averages little more than one per year. The majority of those included in this compendium are too faint to be detected without a fairly large telescope.

As comets approach the Sun they brighten rapidly according to an intensity law of the type $I/I_o = 1/\Delta^2 r^n$ (r = distance from the Sun and Δ = distance from the Earth). The value of the exponent n may vary not only from comet to comet but also from passage to passage of a given comet. Bobrovnikoff (1941-42) found an average value of $n = 3.3$ for $0.38 < r < 3.9$ AU. However many comets have idiosyncracies, in particular, Schwassmann-Wachmann 1 can fluctuate by as much as 5 magnitudes within a few days. Converting the above law to stellar magnitudes gives:

$$m = m_o + 2.5\, n \log r + 5 \log \Delta$$

This equation is quoted for each comet in the data sheets and represents an approximate brightness law calculated from the last observed passage of the comet. The actual observed brightness magnitudes at recovery and perihelion are given with the recovery data. However, the measurement of cometary magnitudes is subject to interpretation by the observer. A quotation from Dr. Elizabeth Roemer (1957), an experienced observer of comets, is included to emphasize the difficulty in accurately predicting the brightness of a comet at a future apparition.

> "At least in the present state of affairs, it is essentially impossible to establish the identity of a comet from photometric evidence. It is not uncommon for estimates of the brightness of comets made from exposures with smaller telescopes to differ rather radically from estimates made from plates exposed with large reflectors, even when very similar methods are employed. A small telescope seems always to make a comet appear relatively brighter than does a large instrument, and the difference may amount to as much as 5 or more magnitudes in spite of all precautions with regard to setting off motion, optimum plate exposure, development, and comparison with good standard magnitude sequences. Overexposed images will make a comet appear brighter as the effect of the coma is added in. A comet is an extended object, and the image builds up more in the course of a prolonged exposure than does the image of a star of comparable brightness. Visual estimates made by comparing a comet with out-of-focus star images also make the comet seem brighter than do estimates made by other methods, again because of the effect of the coma."

2.3 Orbital Parameters

The orbital parameters are given for the last observed passage of the comet and are calculated from the observations at that time. The year of perihelion from which the elements were calculated is given in parenthesis. The accuracy of these parameters as presented is not sufficient for detailed perturbation calculations but is adequate to construct the polar charts which accompany the data sheets.

Comets are subject to continuous perturbation due to their gradual loss of mass (secular perturbation) and due to their gravitational interactions with the planets. The most significant perturbing planet is Jupiter which controls a large group of periodic comets. Even for small perturbations involving changes of less than 1% in the orbital elements, the date of perihelion may be altered by anything from a few days to over six months. Thus it is not adequate to calculate future perihelion dates simply by adding the orbital period to the last perihelion date. This is particularly important when energy calculations are intended to assess the ideal velocity required to intercept the comet near perihelion. The energy requirements depend critically on the relative positions of the Earth and the comet and thus the perihelion time needs to be known to within at least a day. The predicted perihelion dates used later in the data sheets are derived from detailed perturbation calculations performed by ASC/IITRI (Narin, Pierce 1964).

2.4 Physical Appearance

The description of a comet may be divided into the three major components namely the nucleus, the coma and the tail. In practice these divisions are not sharp and have to be interpreted by the observer. The notes describe the appearance of the comet during its last few observed apparitions. Where spectroscopic data is available it is included in the notes. This section summarizes current scientific knowledge of the individual comets and in most cases this knowledge is extremely limited. This is because the faintness and form of most periodic comets do not lend themselves readily to detailed photometric or spectrometric analysis. However this should not be interpreted as a reflection on the overall scientific knowledge of comets, which, although by no means complete, certainly exceeds that of the individual periodic comets considered here. Nevertheless it is one or more of these periodic comets which will probably be chosen for the first missions and the scientific merit of the particular comet must initially be judged on the available data.

2.5 Recent Recoveries

The table of recent recoveries provides data at the time of recovery and at perihelion. This data is of most use when employed in conjunction with the polar chart which shows the relative positions of the Earth and the comet for each perihelion passage. There are a number of conditions which must be fulfilled for the early recovery of a comet. The comet orbit must be adequately known so that its position can be predicted. The comet must be brighter than magnitude 20 at the time it is to be recovered. The Earth-comet positions must be suitable for observation in a night sky without moonlight. At least two hours of visibility must be available for long photographic exposures and this will depend on the position of the observatory and the time of year as well as the position of the comet. A first order estimate of the position, brightness and sighting of the comet can be obtained from the data sheets and the polar charts.

2.6 Polar Chart

The polar chart shows the part of the comet orbit near perihelion and plots the heliocentric latitude projected in the ecliptic plane and the actual Sun-comet distance. The part of the orbit shown with broken lines lies below the ecliptic plane and the inclination of the orbit can be obtained from the orbital parameters. The direction of motion is indicated by the arrows and is directed in every case considered except for Halley's comet which is retrograde. The time markings are in intervals of 50 days. The motion of the Earth is approximately 1° per day counter clockwise and thus the Earth position can be determined for any position of the comet on any passage. For comet positions before perihelion the Earth should be moved the appropriate number of degrees clockwise and for positions after perihelion, counter clockwise. The vernal equinox (♈) is crossed by the Earth on or about March 21st and also on or about September 21 each year.

The effect of the Earth's obliquity can be envisioned if north pole is assumed always to lean 23.5° to the right. Thus at the June solstice the north pole leans 23.5° towards the Sun and at the December solstice it leans 23.5° away from the Sun.

2.7 General Comments

A general description of the comet is given in view of the available data. Comments are made about the accessibility of the comet on future passages in terms of recoverability and observation through perihelion, two important aspects to be taken into account in considering the intercept of a comet with a space probe. The predicted perihelion dates for the comets as shown on the polar chart are derived from perturbation calculations.

2.8 Additional Cometary Data

The median values of the astrophysical properties of comets with periods of less than 100 years are given in Table 1. Tables 2 through 7 list all the comets included in the compendium in order of period, semi-major axis, inclination, eccentricity, perihelion distance and date of perihelion. Table 8 lists the comets which are recommended, on the basis of the data in the compendium, for further consideration for comet missions.

3. SELECTION OF COMETS FOR INTERCEPT MISSIONS

In the first order determination of those comets which are most suitable for intercept by a space probe a number of selection criteria must be fulfilled.

Firstly the recovery of the comet is required at least 60 days before the anticipated launch date. This is to enable the orbit and the perturbation calculations to be verified, to establish that the comet is in fact returning and to permit the maximum accuracy in the prediction of the comet position at intercept. This latter requirement can mean a large saving in the mid-course and terminal propulsion requirements of a mission. The basic conditions for recovery are that the brightness must be greater than magnitude 20 and that the Earth and comet positions should be favorable for photographing the comet in a dark sky for a period of up to two hours. This naturally implies that the comet's position at the time of recovery should be known with reasonable accuracy.

Secondly the comet should be visible from the Earth during the proposed intercept phase of the mission and preferably should be visible from recovery through and beyond intercept. This condition is necessary to make full use of the space probe data by correlation with Earth-based measurements. Continuous observation of the comet can be used to assist in the spacecraft guidance without carrying complicated comet acquisition equipment on board.

The third criterion is that the prior scientific knowledge of the comet should be adequate to give a useful return from the mission. Particularly in the coma and tail of a comet, the density of matter is so low that some knowledge of the constitution of the comet may be required before any valid specification for the scientific instruments can be derived.

Finally, the trajectory analysis must be performed to ensure that the energy requirements of the mission are not excessive and that the time of flight is compatible with the reliability attainable for the mission. The detailed trajectory analysis for comet missions will be reported in the Mission Study Phase of the program (Vickers 1964).

A first order appraisal of these four criteria can be obtained from the data sheets and the polar charts. The method is outlined in Figs. 1,2,3 and 4 just in front of the individual data sheets and polar charts. At any time before perihelion, the relative positions of the Earth and the comet can be located on the polar chart. If the comet-Earth-Sun angle at this time is greater than + 90° then recovery is possible from some latitude on the Earth providing the comet is bright enough. The brightness of the comet can be roughly estimated from previous recoveries and by substitution in the brightness equation. For situations where the comet-Earth-Sun angle is less than $\pm$ 90° but greater than $\pm$ 45°, or where sighting from a particular observatory is required, detailed calculations of the available viewing time may be required and are available using the ASC sighting code (Narin, Pierce 1964). If the comet is in conjunction with the Sun at the times of interest then obviously it cannot be observed.

By comparing the motion of the comet towards perihelion and the motion of the Earth over this period it is possible to estimate whether the comet is observable through and particularly near perihelion. In assessing the value of the mission the data sheets provide what scientific information is available on the comet in terms of size, brightness and constitution and an initial estimate of the scientific return from an intercept mission.

should be possible. If necessary specific ground based observations may be required to clarify some aspects of a comet before a mission can be considered.

Finally the trajectory analysis properly requires detailed calculations of the energy requirements and the time of flight. However the polar chart can be used to set a lower limit to the energy requirements by estimation of the suitability of the Earth and comet positions for a Hohmann type transfer (Fig. 4). The Hohmann energy and flight times are given in Figure 1. If the comet-Sun-Earth angle at launch, i.e., the angle between the comet at perihelion, the Sun and the Earth at a time equal to the Hohmann transfer time before the positions shown on the chart, is 180° then a minimum energy transfer is possible provided the comet is in the ecliptic plane. This can be determined from knowledge of the inclination of the orbit and the nearness of perihelion to an ascending or descending node. It should be noted that all deviations from a true Hohmann transfer in time of flight, flight angles other than 180°, and motion out of the ecliptic plane will increase the energy requirements of the mission. Alternatively summary solar system trajectory data can be used to indicate the important trajectory parameters.

This approximate procedure for sifting out the comets of most interest for intercept missions reduces the list considerably as is shown in Table 8. Thereafter detailed calculations and analyses are necessary for each possible recovery and launch opportunity. This preliminary list will be further reduced and the favorable missions discussed in more detail in the mission study and the trajectory analysis reports.

4. CONCLUSIONS

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This compendium of data presents ordered information on all periodic comets which have already been observed twice and which are expected to pass perihelion within the next 25 years. The fact that the data is sparse for many of the comets reflects the limited present knowledge of those comets. In addition to the retrospective data there are also included predictions of the future dates of perihelion, within the time period considered which are based on detailed perturbation calculations. Nevertheless for the first missions to intercept a comet, it will be necessary to recover and check the position and orbit of the comet before the space probe is launched.

The periodic comet of outstanding scientific interest is Halley's comet which is due to return in 1986. It is large and bright, it approaches close to the Earth, it was extensively observed from the Earth on its last passage in 1910 and it emits both gas molecules and dust quite profusely. From the scientific standpoint it would appear that a valuable experiment will be to send a probe through the coma and tail of Halley's comet and to pass as near the nucleus as possible. However due to its long orbital period and the potential scientific value of an intercept with Halley's comet, it would seem advisable to launch some comet probes before 1986 so that the experimental techniques can be evaluated and perfected. Suitable comets are listed in Table 8.

Author

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Table 1

MEDIAN PARAMETERS OF COMETS WITH PERIODS LESS THAN 100 YEARS

Positional Elements	Value
Mean number of appearance	4
Median period	7 years
Median inclination	15° (11° for P $<$ 10 years)
Median eccentricity	0.56 (lowest = 0.135)
Median perihelion distance	1.3 AU
Median Aphelion distance	5.5 AU
Median semi-major axis	3.6 AU
Orbital direction	Direct (exception Halley)
Physical Elements	
Diameter of coma	20,000 - 2,000,000 km
Diameter of central condensation	2000 km
Ion densities in coma	10^4 - 10^6 ions/cm^3
Diameter of nucleus	1 - 10 km
Length of tail (visible to eye)	10 x 10^6 km (up to 150 x 10^6 km)
Solar distance at which tail appears	1.7 AU
Upper limit of mass for large comets	6 x 10^{18} gm
For faint small comets	6 x 10^{14} gm
Average density of coma or head	10^{-12} gm/cc
Average density of tail	10^{-24} gm/cc
Median absolute magnitude at r = 1, Δ = 1	
First appearance	9 magnitude
Last appearance	10 magnitude
Faint comets	18 - 19 magnitude
Change of magnitude with solar and terrestrial distances r and Δ	$m = m + 2.5\, n \log r + 5 \log \Delta$, where $n = 4.5 \pm 1.5$ (n not necessarily constant for any comet)

Table 1 (Cont'd)

Spectra (atoms, molecules, ions, continuum)

Nucleus

Strong solar continuum with Fraunhofer lines, CH, CH_2 (tentative)

Coma

Solar continuum also usually present, C_2 (swan bands), CH (violet and red bands), CH (3900 bands), OH (3064 system), NH (3360 system), C_3 (4050 group), OH^+ (tentative), CH^+ (fairly well established), NH_2 (?), Na-D lines (the sodium D-doublet appears in emission in the central part of the head. Some observers have reported Fe and Ni lines also.)

Tail

Solar continuum may be present at small heliocentric distances. Only molecular ions are found at large distances from the head. CO^+ major constituent (Baldet-Johnson band), N_2^+ major constituent (comet tail band), CH^+ minor constituent, OH^+, CO_2^+, some unassigned emission.

Table 2

THE COMETS IN ORDER OF PERIOD

Comet Name	No. of Observed Passes	Period (yrs)
1. Encke	47	3.30
2. Grigg-Skjellerup	10	4.91
3. Honda-Mrkos-Pajdusakova	2	5.21
4. Tempel 2	13	5.26
5. Tuttle-Giacobini-Kresak	4	5.49
6. Pons-Winnecke	15	6.29
7. Kopff	8	6.32
8. Giacobini-Zinner	7	6.42
9. Forbes	4	6.42
10. Wolf-Harrington	3	6.53
11. Schwassmann-Wachmann 2	6	6.53
12. Wirtanen	3	6.67
13. D'Arrest	10	6.67
14. Perrine-Mrkos	4	6.71
15. Reinmuth 2	3	6.71
16. Brooks 2	10	6.72
17. Arend-Rigaux	2	6.80
18. Harrington	2	6.80
19. Johnson	3	6.86
20. Finlay	7	6.90
21. Borrelly	7	7.02
22. Daniel	4	7.09
23. Harrington-Abell	2	7.24
24. Faye	15	7.38
25. Whipple	5	7.46
26. Ashbrook-Jackson	3	7.52
27. Reinmuth 1	4	7.65
28. Arend	2	7.79
29. Oterma	Annual	7.93
30. Schaumasse	6	8.18
31. Wolf	10	8.43
32. Comas Sola	5	8.59
33. Vaisala 1	3	10.5
34. Neujmin 3	2	10.5
35. Tuttle	8	13.7
36. Schwassmann-Wachmann 1	Annual	16.1
37. Neujmin 1	3	17.9
38. Halley	29	76.0

Table 3

THE COMETS IN ORDER OF SEMI-MAJOR AXIS

Comet Name	Semi-Major Axis (AU)
1. Encke	2.22
2. Crigg-Skjellerup	2.88
3. Honda-Mrkos-Pajdusakova	3.00
4. Tempel 2	3.02
5. Tuttle-Giacobini-Kresak	3.11
6. Pons-Winnecke	3.41
7. Kopff	3.42
8. Giacobini-Zinner	3.45
9. Forbes	3.45
10. Wolf-Harrington	3.49
11. Schwassmann-Wachmann 2	3.49
12. Wirtanen	3.54
13. D'Arrest	3.54
14. Perrine-Mrkos	3.56
15. Reinmuth 2	3.56
16. Brooks 2	3.56
17. Arend-Rigaux	3.59
18. Harrington	3.59
19. Johnson	3.61
20. Finlay	3.61
21. Borrelly	3.66
22. Daniel	3.69
23. Harrington-Abell	3.74
24. Faye	3.79
25. Whipple	3.80
26. Ashbrook-Jackson	3.83
27. Reinmuth 1	3.88
28. Arend	3.93
29. Oterma	3.98
30. Schaumasse	4.06
31. Wolf	4.14
32. Comas Sola	4.19
33. Vaisala 1	4.78
34. Neujmin 3	4.82
35. Tuttle	5.74
36. Schwassmann-Wachmann 1	6.21
37. Neujmin 1	6.85
38. Halley	17.8

Table 4

THE COMETS IN ORDER OF INCLINATION

Comet Name	Inclination (degrees)
1. Finlay	3.6
2. Schwassmann-Wachmann 2	3.72
3. Neujmin 3	3.8
4. Oterma	4.0
5. Forbes	4.6
6. Kopff	4.7
7. Brooks 2	5.6
8. Reinmuth 2	6.99
9. Reinmuth 1	8.40
10. Harrington	8.7
11. Faye	9.1
12. Schwassmann-Wachmann 1	9.5
13. Whipple	10.2
14. Vaisala 1	11.3
15. Encke	11.9
16. Schaumasse	12.0
17. Tempel 2	12.5
18. Ashbrook-Jackson	12.5
19. Honda-Mrkos-Pajdusakova	13.2
20. Wirtanen	13.4
21. Comas Sola	13.4
22. Tuttle-Giacobini-Kresak	13.8
23. Johnson	13.87
24. Neujmin 1	15.1
25. Harrington-Abell	16.8
26. Grigg-Skjellerup	17.6
27. Perrine Mrkos	17.7
28. Arend-Rigaux	17.8
29. D'Arrest	18.1
30. Wolf-Harrington	18.5
31. Daniel	20.13
32. Arend	21.6
33. Pons-Winnecke	22.3
34. Wolf	27.3
35. Giacobini-Zinner	30.9
36. Borrelly	31.1
37. Tuttle	54.7
38. Halley	162.2 (retrograde)

Table 5

THE COMETS IN ORDER OF ECCENTRICITY

	Comet Name	Eccentricity
1.	Schwassmann-Wachmann 1	0.132
2.	Oterma	0.147
3.	Whipple	0.356
4.	Johnson	0.377
5.	Schwassmann-Wachmann 2	0.382
6.	Wolf	0.395
7.	Ashbrook-Jackson	0.398
8.	Reinmuth 2	0.457
9.	Reinmuth 1	0.478
10.	Brooks 2	0.505
11.	Harrington-Abell	0.523
12.	Arend	0.534
13.	Wolf-Harrington	0.540
14.	Wirtanen	0.543
15.	Tempel 2	0.550
16.	Daniel	0.550
17.	Forbes	0.553
18.	Kopff	0.556
19.	Harrington	0.559
20.	Faye	0.576
21.	Comas Sola	0.576
22.	Neujmin 3	0.591
23.	Arend-Rigaux	0.600
24.	Borrelly	0.603
25.	D'Arrest	0.614
26.	Vaisala 1	0.636
27.	Tuttle-Giacobini-Kresak	0.639
28.	Pons-Winnecke	0.639
29.	Perrine-Mrkos	0.644
30.	Finlay	0.703
31.	Grigg-Skjellerup	0.703
32.	Schaumasse	0.705
33.	Giacobini-Zinner	0.724
34.	Neujmin 1	0.774
35.	Honda-Mrkos-Pajdusakova	0.815
36.	Tuttle	0.820
37.	Encke	0.847
38.	Halley	0.967

Table 6

THE COMETS IN ORDER OF PERIHELION DISTANCE

Comet Name	Perihelion Distance (AU)
1. Encke	0.34
2. Honda-Mrkos-Pajdusakova	0.56
3. Halley	0.59
4. Grigg-Skjellerup	0.86
5. Giacobini-Zinner	0.94
6. Tuttle	1.03
7. Finlay	1.08
8. Tuttle-Giacobini-Kresak	1.12
9. D'Arrest	1.16
10. Schaumasse	1.19
11. Pons-Winnecke	1.23
12. Perrine-Mrkos	1.27
13. Tempel 2	1.36
14. Arend-Rigaux	1.43
15. Borrelly	1.45
16. Kopff	1.52
17. Forbes	1.54
18. Neujmin 1	1.55
19. Harrington	1.58
20. Wolf-Harrington	1.61
21. Faye	1.61
22. Wirtanen	1.62
23. Daniel	1.66
24. Vaisala 1	1.74
25. Brooks 2	1.76
26. Comas Sola	1.78
27. Harrington-Abell	1.78
28. Arend	1.83
29. Reinmuth 2	1.93
30. Neujmin 3	1.97
31. Reinmuth 1	2.03
32. Schwassmann-Wachmann 2	2.16
33. Johnson	2.26
34. Ashbrook-Jackson	2.31
35. Whipple	2.45
36. Wolf	2.51
37. Oterma	3.39
38. Schwassmann-Wachmann 1	5.54

Table 7

FUTURE PERIHELION DATES OF THE PERIODIC COMETS

1964	March	Pons-Winnecke
	April	Daniel
	May	Kopff
	June	Arend-Rigaux
	Sept	Honda-Mrkos-Pajdusakova
1965	Feb	Wolf-Harrington
	Aug	Reinmuth 1
1966	March	Giacobini-Zinner
	Dec	Neujmin 1
1967	Jan	Grigg-Skjellerup
	March	Brooks 2
	April	Harrington
	April	Tuttle
	June	Arend
	June	Borrelly
	July	Finlay
	Aug	Reinmuth 2
	Aug	Tempel 2*
	Aug	Wolf
	Sept	Encke
	Nov	Tuttle-Giacobini-Kresak
	Dec	Forbes
	Dec	Wirtanen
1968	March	Schwassmann-Wachmann 2*
	July	Schaumasse
	Oct	Perrine-Mrkos*
1969	May	Harrington-Abell
	Sept	Honda-Mrkos-Pajdusakova
	Oct	Comas Sola
	Oct	Faye
1970	March	Johnson
	May	D'Arrest
	July	Pons-Winnecke*
	Oct	Kopff*
	Oct	Whipple
1971	Jan	Encke
	Mar	Ashbrook-Jackson
	April	Arend-Rigaux
	May	Daniel
	Aug	Wolf-Harrington
	Sept	Vaisala 1
1972	March	Grigg-Skjellerup
	May	Neujmin 3
	Aug	Giacobini-Zinner*
	Nov	Tempel 2
1973	March	Reinmuth 1
	June	Tuttle-Giacobini-Kresak*
1974	Jan	Brooks 2
	Feb	Harrington
	April	Encke*
	May	Borrelly
	May	Forbes
	May	Reinmuth 2
	July	Finlay
	July	Wirtanen
	Sept	Schwassmann-Wachmann 2
	Dec	Honda-Mrkos-Pajdusakova
1975	May	Arend
	Aug	Perrine-Mrkos
1976	Jan	Wolf
	April	Harrington-Abell
	Aug	D'Arrest*
	Sept	Schaumasse
	Nov	Pons-Winnecke

* Comets recommended for further consideration (see Table 8).

Table 7 (Cont'd)

1977	Jan	Johnson
	Feb	Faye
	March	Kopff
	April	Grigg-Skjellerup*
	Aug	Encke
1978	Jan	Arend-Rigaux*
	Feb	Tempel 2
	March	Whipple
	March	Wolf-Harrington
	July	Daniel
	Aug	Ashbrook-Jackson*
	Sept	Comas Sola
1979	Jan	Tuttle-Giacobini-Kresak
	Feb	Giacobini-Zinner
1980	April	Honda-Mrkos-Pajdusakova
	May	Wirtanen
	Sept	Forbes
	Oct	Reinmuth 1
	Nov	Brooks 2
	Dec	Encke
	Dec	Harrington
1981	Jan	Reinmuth 2
	Jan	Tuttle*
	Feb	Borrelly
	March	Schwassmann-Wachmann 2*
	June	Finlay
1982	May	Grigg-Skjellerup
	May	Perrine-Mrkos
	Aug	Vaisala 1
	Oct	D'Arrest
	Dec	Neujmin 3
1983	April	Pons-Winnecke
	May	Tempel 2
	Aug	Kopff*
	Nov	Johnson
1984	March	Encke*
	May	Wolf
	July	Faye
	Aug	Tuttle-Giacobini-Kresak
	Sept	Wolf-Harrington
	Oct	Neujmin 1
	Nov	Arend-Rigaux*
	Dec	Schaumasse
1985	May	Honda-Mrkos-Pajdusakova
	Sept	Giacobini-Zinner*
1986	Jan	Ashbrook Jackson
	Jan	Harrington-Abell
	April	Halley*

* Comets recommended for further consideration (see Table 8).

Table 8

COMETS SELECTED AS WORTHY OF DETAILED CONSIDERATION FOR MISSIONS

(Based on Data Sheets and Polar Charts)

Comet	Date of Perihelion	Recovery	Observation at Perihelion	Present Scientific Knowledge
Tempel 2	Aug 1967	V. good	V. good	Some spectroscopic data
Schwassmann-Wachmann 2	Mar 1968	Good	Good	Diffuse, dusty comet
Perrine-Mrkos	Oct 1968	Good	Excellent	Not well known
Pons-Winnecke	July 1970	Good	Good	Good spectroscopic data
Kopff	Oct 1970	Good	Good	Not well known
Giacobini-Zinner	Aug 1972	F. good	V. good	Well known dusty comet
Tuttle-Giacobini-Kresak	June 1973	Good	Good	Not well known
Encke	April 1974	Good	Fair	Very well known (gaseous)
D'Arrest	Aug 1976	V. good	Excellent	No spectroscopic data. Seen 10 times
Grigg-Skjellerup	April 1977	Good	Excellent	Not well known
Arend-Rigaux	Jan 1978	Good	F. good	Not well known
Ashbrook-Jackson	Aug 1978	V. good	Good	Not well known
Tuttle	Jan 1981	Good	Excellent	No spectroscopic data
Schwassmann-Wachmann 2	March 1981	Good	Good	Diffuse dusty comet
Kopff	Aug 1983	Good	Good	Not well known
Encke	March 1984	Good	Fair	Very well known (gaseous)
Arend-Rigaux	Nov 1984	F. good	F. good	Not well known
Giacobini-Zinner	Sept 1985	Good	V. good	Well known dusty comet
Halley	April 1986	Good	Excellent	Very well known

F = Fairly V = Very

DATA SHEETS AND POLAR CHARTS FOR THE COMETS

Figures 1, 2, 3, 4 at the front of this section are included to assist in the use of the data sheets and polar charts.

The comets are arranged in alphabetical order.

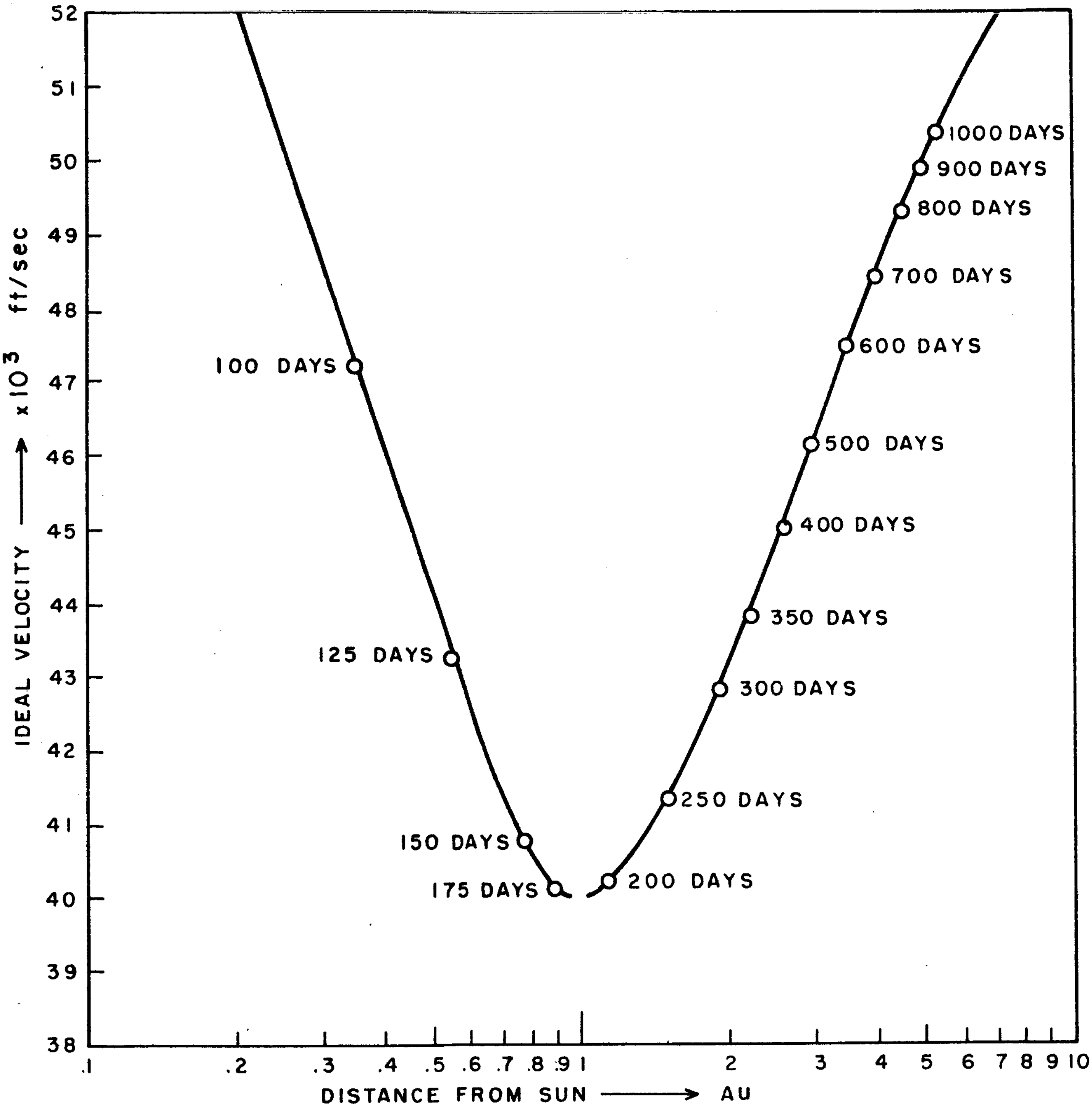
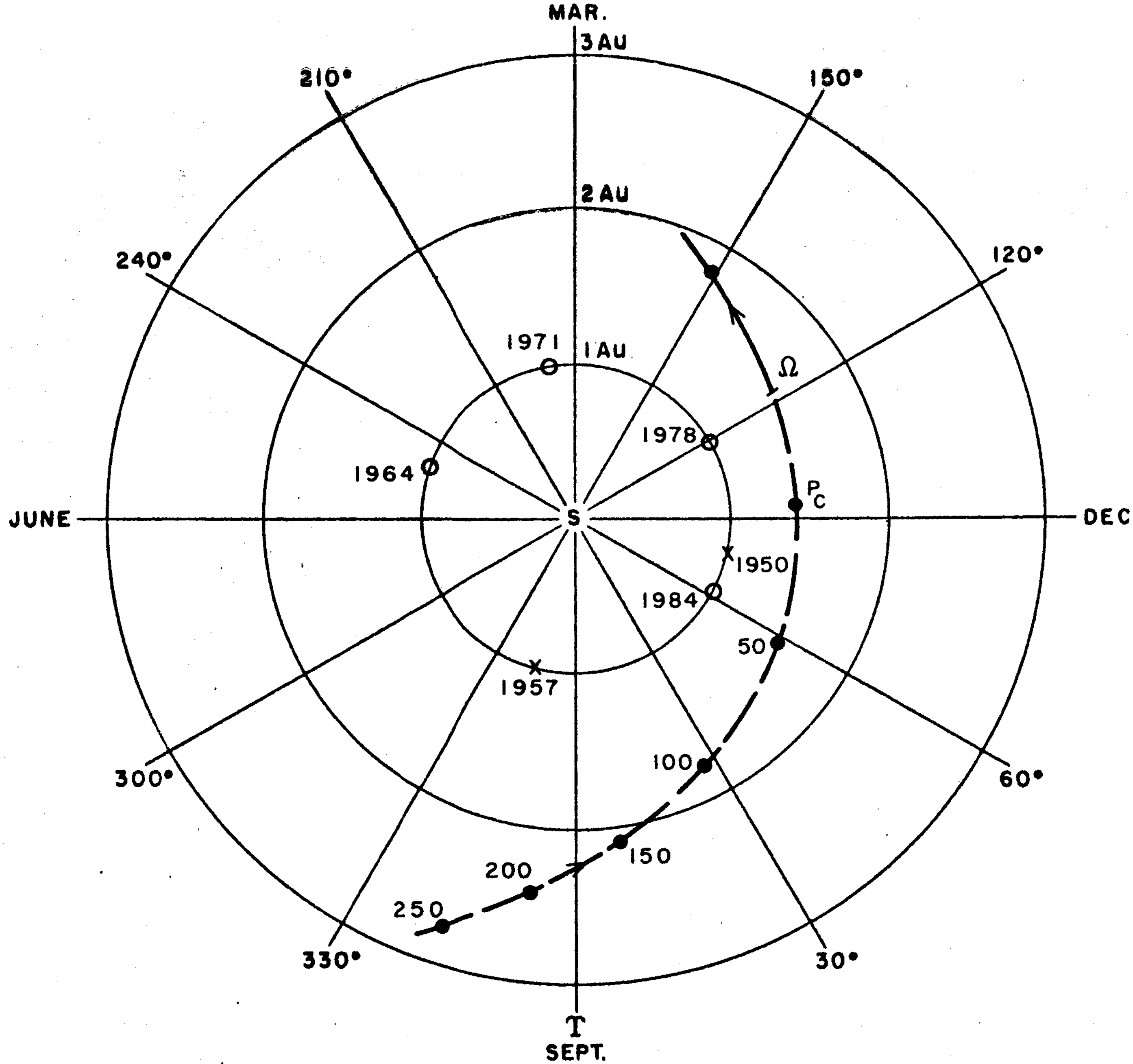


Fig. 1 IDEAL VELOCITY AND TIME OF FLIGHT FOR HOHMANN TRANSFERS TO HELIOCENTRIC DISTANCES BETWEEN 0.2 AND 7 AU

AREND-RIGAUX



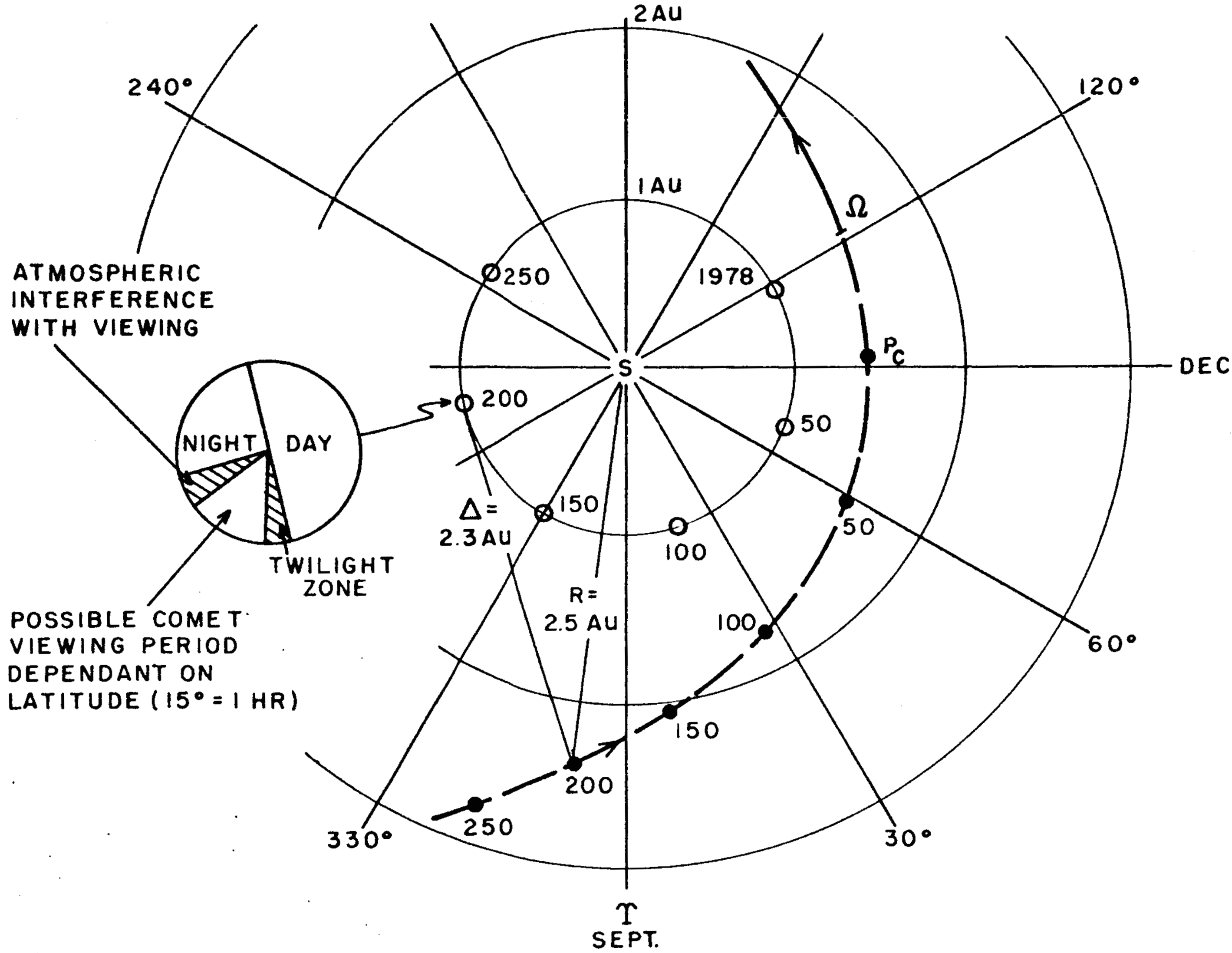
P_C = PERIHELION OF COMET

● = POSITION OF COMET AT STATED NUMBER OF DAYS BEFORE PERIHELION

X = PAST POSITIONS OF EARTH AT PERIHELON OF COMET

O = PREDICTED POSITIONS OF EARTH AT PERIHELION OF COMET (SEE SECT. 2·3)

Fig. 2 EXAMPLE OF A COMET POLAR CHART SHOWING THE DIRECTION OF THE COMET IN ITS ORBIT AND ASCENDING NODE. THE EARTH POSITIONS ARE SHOWN FOR SUCCESSIVE PERIHELIA OF THE COMET FROM 1950 TO 1984

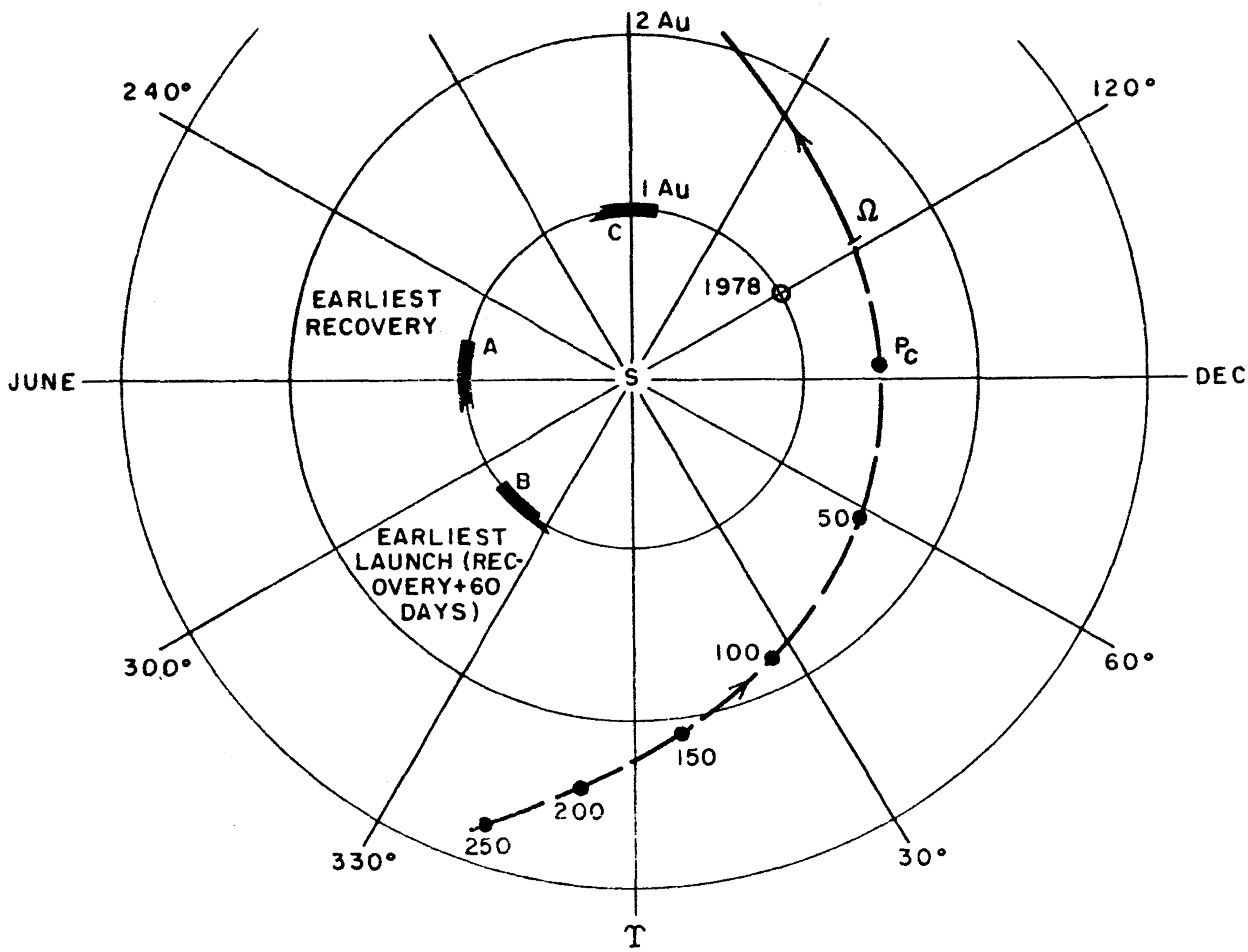


Comet: Arend-Rigaux Perihelion: 26 January 1978 Inclination: 17.8°

Time before Perihelion	r	Δ	Mag.	Comet-Earth -Sun Angle	Observable
150 days	2.1 AU	1.5 AU	17.7	115°	Yes
200 days	2.5 AU	2.3 AU	19.5	90°	Probably
250 days	2.8 AU	3.2 AU	21.3	55°	No

During recovery the comet is below the ecliptic plane and will therefore be difficult to observe from high northern latitudes in the summer months. However from observatories at low latitudes the comet should be recovered 210 to 230 days before perihelion. It will be observable from recovery through and beyond perihelion.

Fig. 3 RECOVERY ANALYSIS USING THE POLAR CHART



Comet: Arend-Rigaux Perihelion: 26 January 1978 Inclination: 17.8°

Hohmann transfer to perihelion at 1.4 AU: ΔV = 41,000 ft/sec TF = 230 days
Recovery anticipated: less than 230 days before perihelion (Region A)

Therefore earliest launch date (recovery plus 60 days): less than 170 days before perihelion (Region B).
However Region B is almost 180° from the ascending node (Ω) which is only 50 days after perihelion. This would seem a good point to intercept the comet.

Therefore max flight time = 170 + 50 = 220 days
distance of node (r) = 1.5 AU
flight angle ≃ 180°

These flight parameters are not largely different from the Hohmann transfer and therefore a low energy mission should be possible.

Δ at intercept = 1.5 AU
Brightness at intercept = mag 15

The comet is not well known and will be fairly faint at intercept. Spectroscopic analysis will not be possible from Earth. This mission is thus of questionable scientific value despite the probable low ideal velocity requirement.

Fig. 4 APPROXIMATE MISSION ANALYSIS

PERIODIC COMET AREND

HISTORICAL: Discovered in 1951 just before perihelion. Recovered in 1959 again just before perihelion due to relatively poor observing conditions.

BRIGHTNESS: (See Section 2.4)

$$m = 11.5 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1959)

Period (P)	= 7.79 yrs	Eccentricity (e)	= 0.534
Semi-major axis (a)	= 3.93 AU	Long. asc. node (Ω)	= 357.6°
Inclination (i)	= 21.6°	Arg. perihelion (ω)	= 44.5°

PHYSICAL APPEARANCE:

Nucleus A small but diffuse object beyond 2 AU but usually a well condensed nucleus through perihelion.

Coma Fairly large coma at perihelion. (Elliptical shape in 1951.)

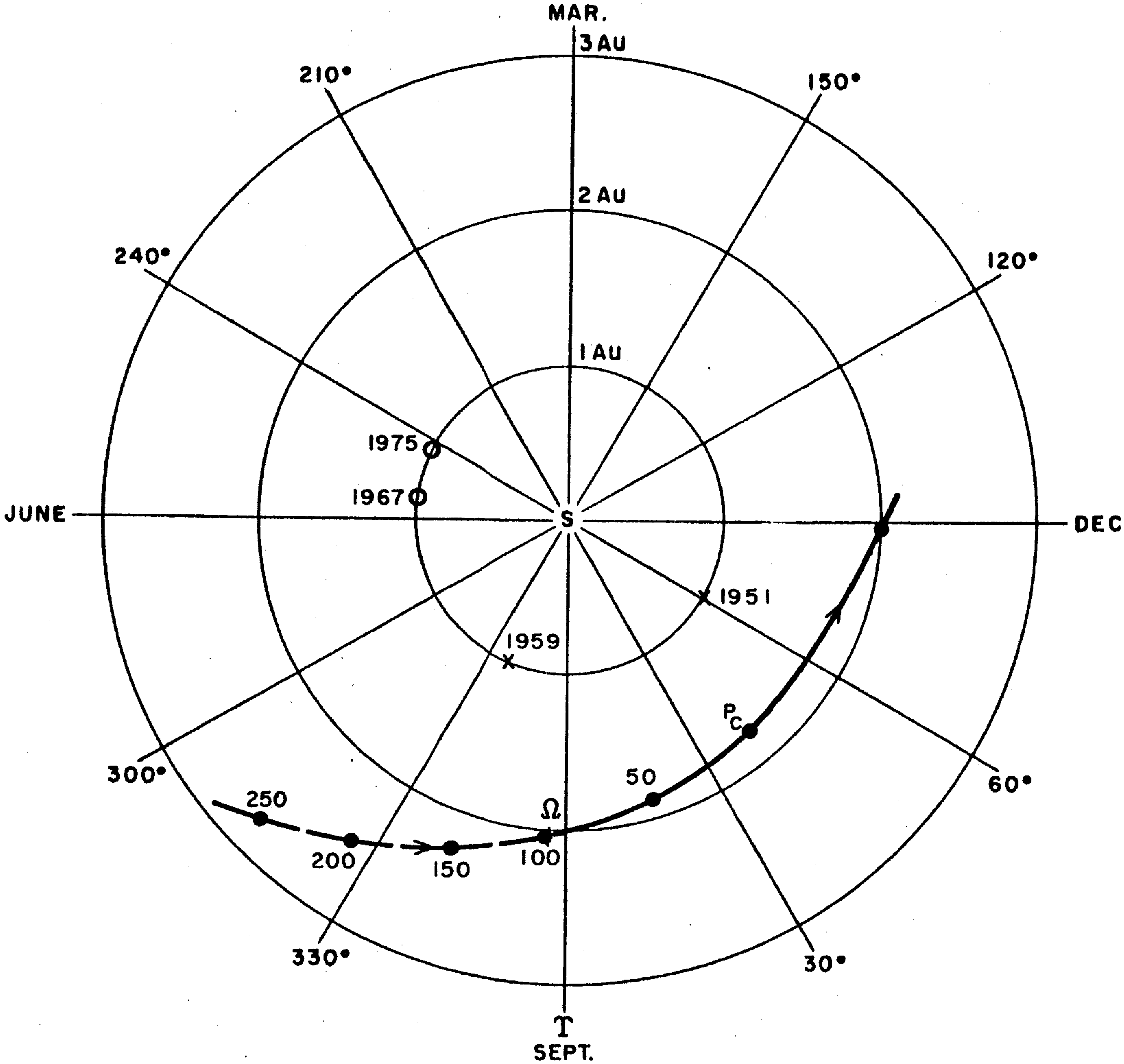
Tail A faint trace of a tail has been observed after perihelion.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
57	19.2	1.9 AU	Fair	1 Sep 59	18	Fair	210
50	15	1.9 AU	Discovered	23 Nov 51	14	Good	200

GENERAL COMMENTS: A generally faint comet which has been brightest after perihelion. Recovery and observation at perihelion are expected to be poor in 1967 and 1975, although it may possibly be recovered before conjunction with the Sun (i.e., 180 days). Its period will be increased during the next 15 years to approach a period of 8 years. This comet is too faint and badly placed for missions in the next 25 years.

ARENDS



P_C = PERIHELION OF COMET

● = POSITION OF COMET AT STATED NUMBER OF DAYS BEFORE PERIHELION

X = PAST POSITIONS OF EARTH AT PERIHELON OF COMET

O = PREDICTED POSITIONS OF EARTH AT PERIHELION OF COMET (SEE SECT. 2·3)

PERIODIC COMET AREND-RIGAUX

HISTORICAL: Discovered in 1951, nearly 2 months after perihelion, and reobserved in 1958 again after perihelion. It passes up through the ecliptic a month after perihelion. It suffered a perturbation in 1960 and may not be observed in 1964.

BRIGHTNESS: (See Section 2.4)

$$m = 12 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1963)

Period (P)	= 6.80 yrs	Eccentricity (e)	= 0.600
Semi-major axis (a)	= 3.59 AU	Long. asc. node (Ω)	= 122°
Inclination (i)	= 17.8°	Arg. perihelion (ω)	= 328°

PHYSICAL APPEARANCE:

Nucleus Almost stellar nucleus on discovery 50 days after perihelion with a magnitude of 14.5. The nucleus remained almost stellar through the observation period. It was also stellar in 1958.

Coma Small diffuse coma of total magnitude 12 on discovery in 1951. No coma could be detected 150 days after perihelion in 1958 (mag 19).

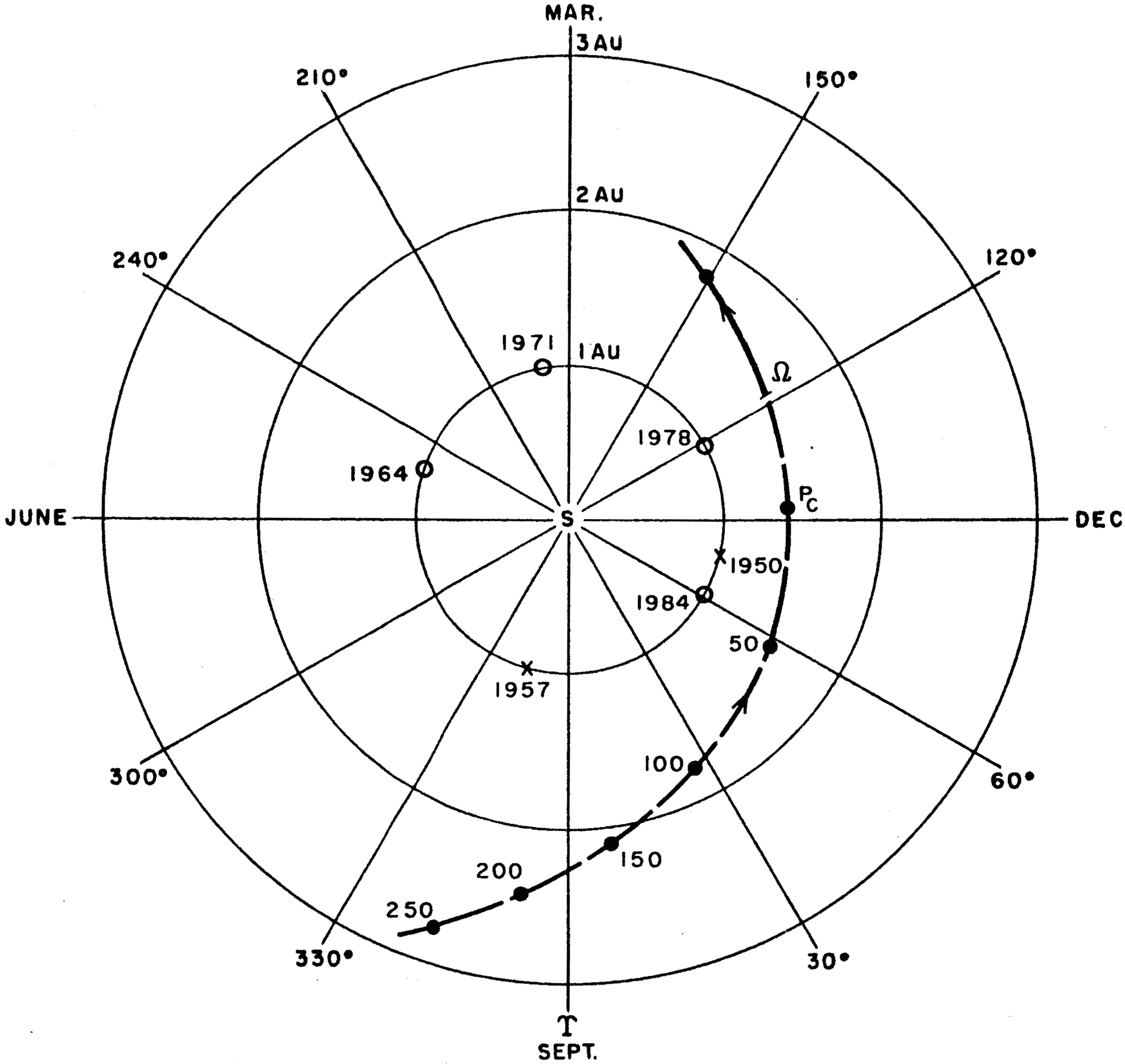
Tail Short very weak tail in 1951 but no tail observed in 1958.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
150 after	19	2 AU	Poor	6 Sep 57	--	Poor	123
50 after	12	1.5 AU	Discovered	18 Dec 50	--	----	100

GENERAL COMMENTS: This comet has only been seen beyond 1.5 AU after perihelion. Its brightness faded rapidly in both apparitions. Poor observation conditions delayed recovery on its first predicted return. The only good apparitions expected in the period considered will be in 1978 and 1984. Recovery and observation through perihelion will be optimum in 1978 but the general faintness of the comet will make it questionable for a mission.

AREND-RIGAUX



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PERIODIC COMET ASHBROOK-JACKSON

HISTORICAL: Discovered in 1948 after a major perturbation by Jupiter and reobserved in 1956 and 1962.

BRIGHTNESS: (See Section 2.4)

$$m = 11.5 + 10 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1963)

Period (P)	= 7.52 yrs	Eccentricity (e)	= 0.398
Semi-major axis (a)	= 3.83 AU	Long. asc. node (Ω)	= 2.30°
Inclination (i)	= 12.5°	Arg. perihelion (ω)	= 348.8°

PHYSICAL APPEARANCE:

Nucleus The comet is asteroidal in appearance beyond 3 AU and the nucleus remains well condensed throughout its apparitions. Estimated to have a nucleus of diameter greater than 10 km which was estimated as magnitude 10 in 1948.

Coma The coma is well defined through perihelion but tends to be diffuse beyond 200 days from perihelion. It was observed at 20 mag 500 days before perihelion in 1962.

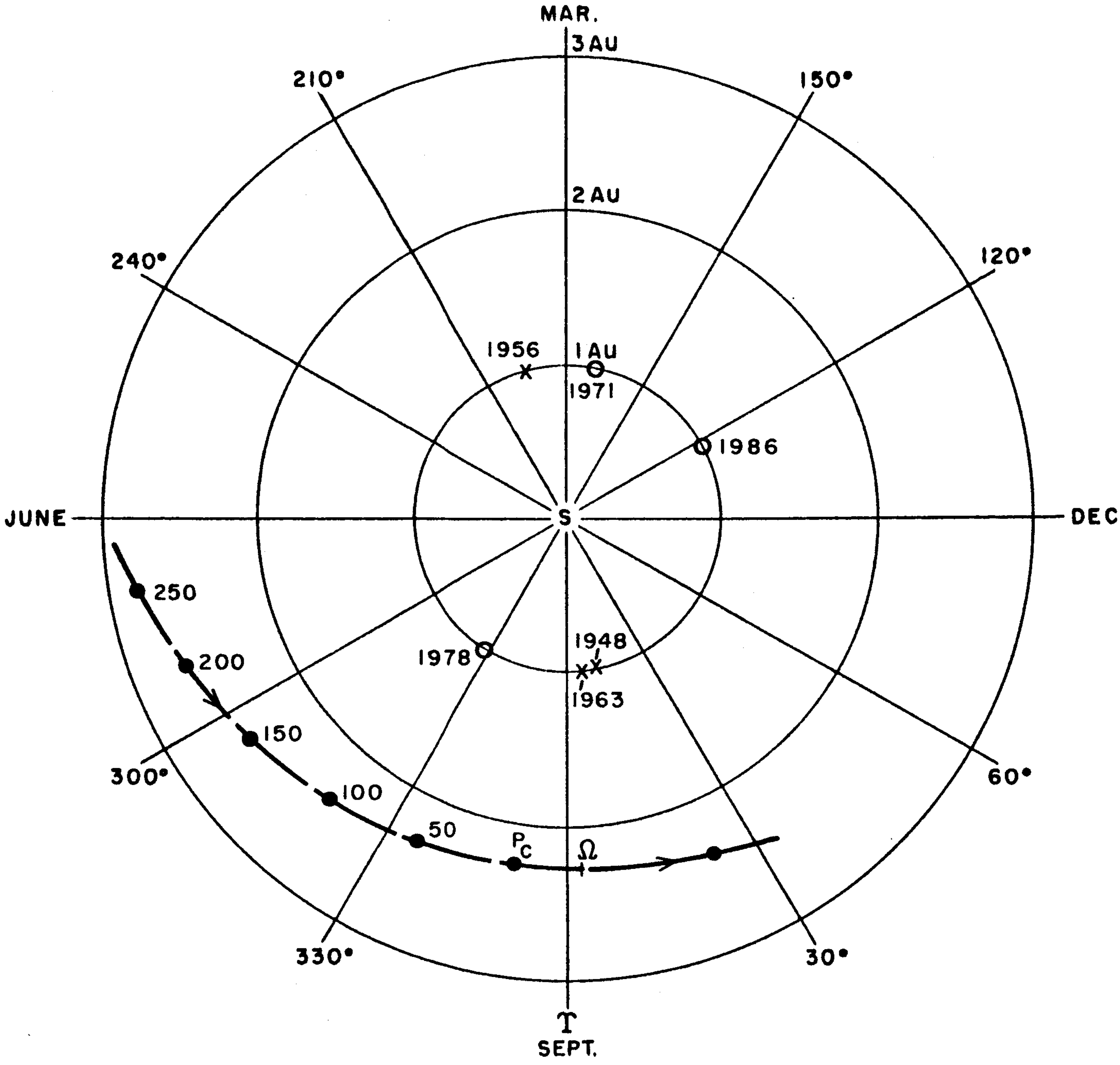
Tail A short but fairly broad tail has been seen on each apparition of Ashbrook-Jackson.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
500	20	>3 AU	Fair	1 Oct 63	?	Good	?
340	17	>3 AU	F. good	5 Apr 56	--	Poor	200
38	11	2.4 AU	Discovered	4 Oct 48	11	Good	180

GENERAL COMMENTS: A comet of average brightness but which sometimes has appeared 2 or 3 magnitudes fainter than expected. Its orbit makes it potentially visible for very long arcs which are interupted every 8 months or so as the comet goes into conjunction with the Sun. Early recovery can be difficult from the northern hemisphere. The 1978 apparition will be the best for recovery and brightness at perihelion and it should be considered as a target then.

ASHBROOK - JACKSON



P_C = PERIHELION OF COMET

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PERIODIC COMET BORRELLY

HISTORICAL: Discovered in 1905 with the apparition in 1960 being the seventh to be observed. Its ascending node is near the orbit of Jupiter which makes it subject to occasional large perturbations despite its high inclination.

BRIGHTNESS: (See Section 2.4)

$$m = 10 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1960)

Period (P)	= 7.02 yrs	Eccentricity (e)	= 0.603
Semi-major axis (a)	= 3.66 AU	Long. asc. node (Ω)	= 76.23°
Inclination (i)	= 31.1°	Arg. perihelion (ω)	= 350.75°

PHYSICAL APPEARANCE:

Nucleus The nucleus is well condensed appearing almost stellar at solar distances greater than 2 AU. Gaseous comet with no continuum in its emission spectrum.

Coma Generally diffuse small coma. Emissions show presence of CN, C_2, C_3 and CH. $C_3 > CN$.

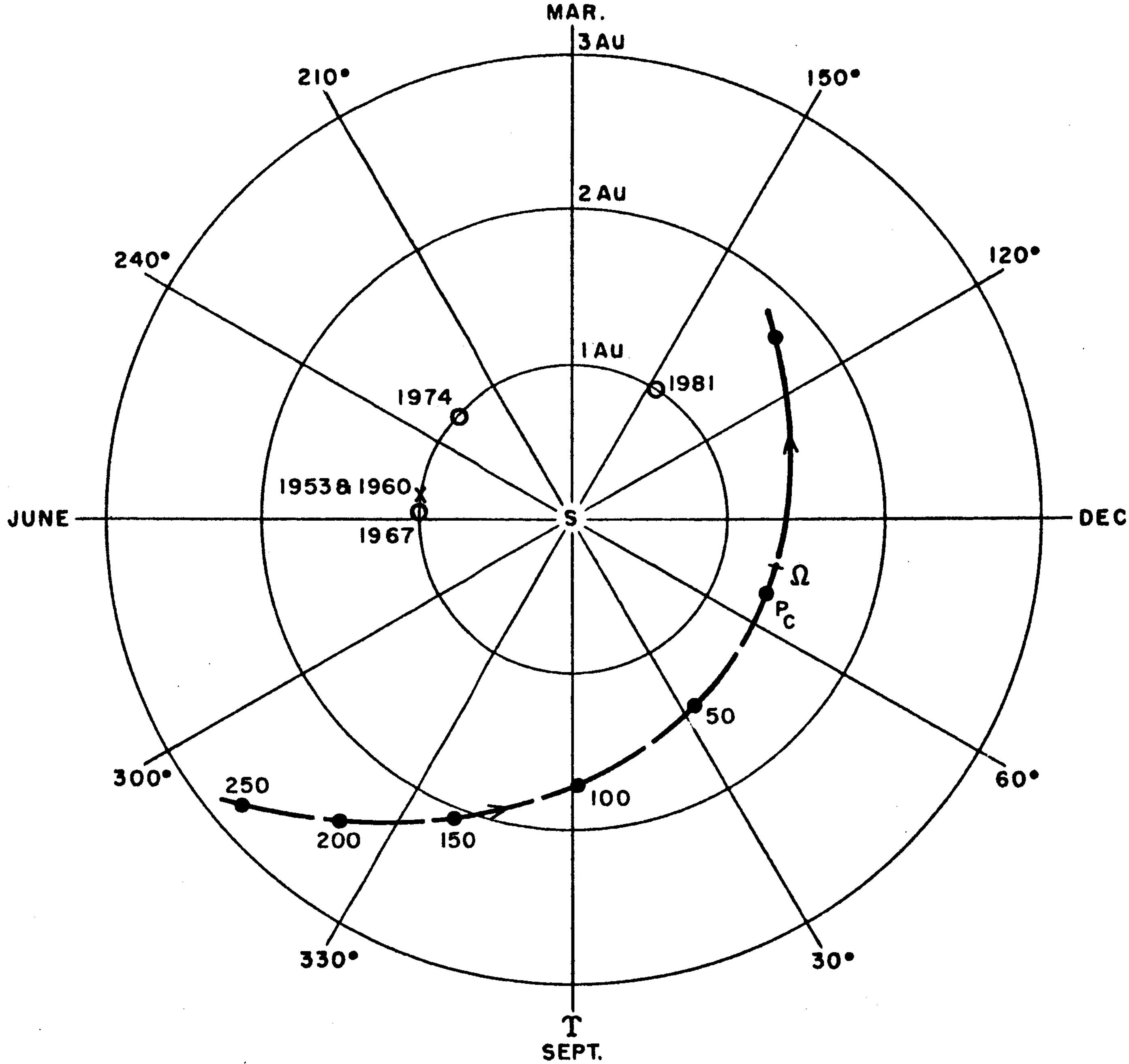
Tail A definite tail is associated with Borrelly.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
84 after	16	1.7 AU	Fair	13 Jun 60	--	Poor	168
240 after	19.5	2.8 AU	Fair	8 Jun 53	--	Poor	20
Not seen in 1946							
Not seen in 1939							

GENERAL COMMENTS: It is continuously difficult to observe Borrelly for many months before and after perihelion due to the relative positions of the Earth, Sun and comet. Perturbations are gradually increasing the eccentricit and reducing the period. The 1981 pass is the best in the next 25 years although the comet will be fairly faint at perihelion.

BORRELLY



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PERIODIC COMET BROOKS (2)

HISTORICAL: Discovered in 1889 after a highly perturbing approach to Jupiter. It has since only been missed in 1918.

BRIGHTNESS: (See Section 2.4)

$$m = 10.0 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1962)

Period (P)	= 6.72 yrs	Eccentricity (e)	= 0.505
Semi-major axis (a)	= 3.56 AU	Long. asc. node (Ω)	= 176.9°
Inclination (i)	= 5.57°	Arg. perihelion (ω)	= 197.1°

PHYSICAL APPEARANCE:

Nucleus   Nucleus split into four fragments in 1889 with one fragment persisting. Stellar nucleus at distances greater than 2.5 AU from the Sun. Upper limit of diameter calculated as 2.4 km.

Coma   Generally faint small coma which is strongly condensed more than 100 days from perihelion. Total magnitude of only 17 in the poor observation conditions of 1960. A magnitude of 20.2 was detected at a solar distance of 2.7 AU. CN is the strongest band in the spectrum together with a continuum.

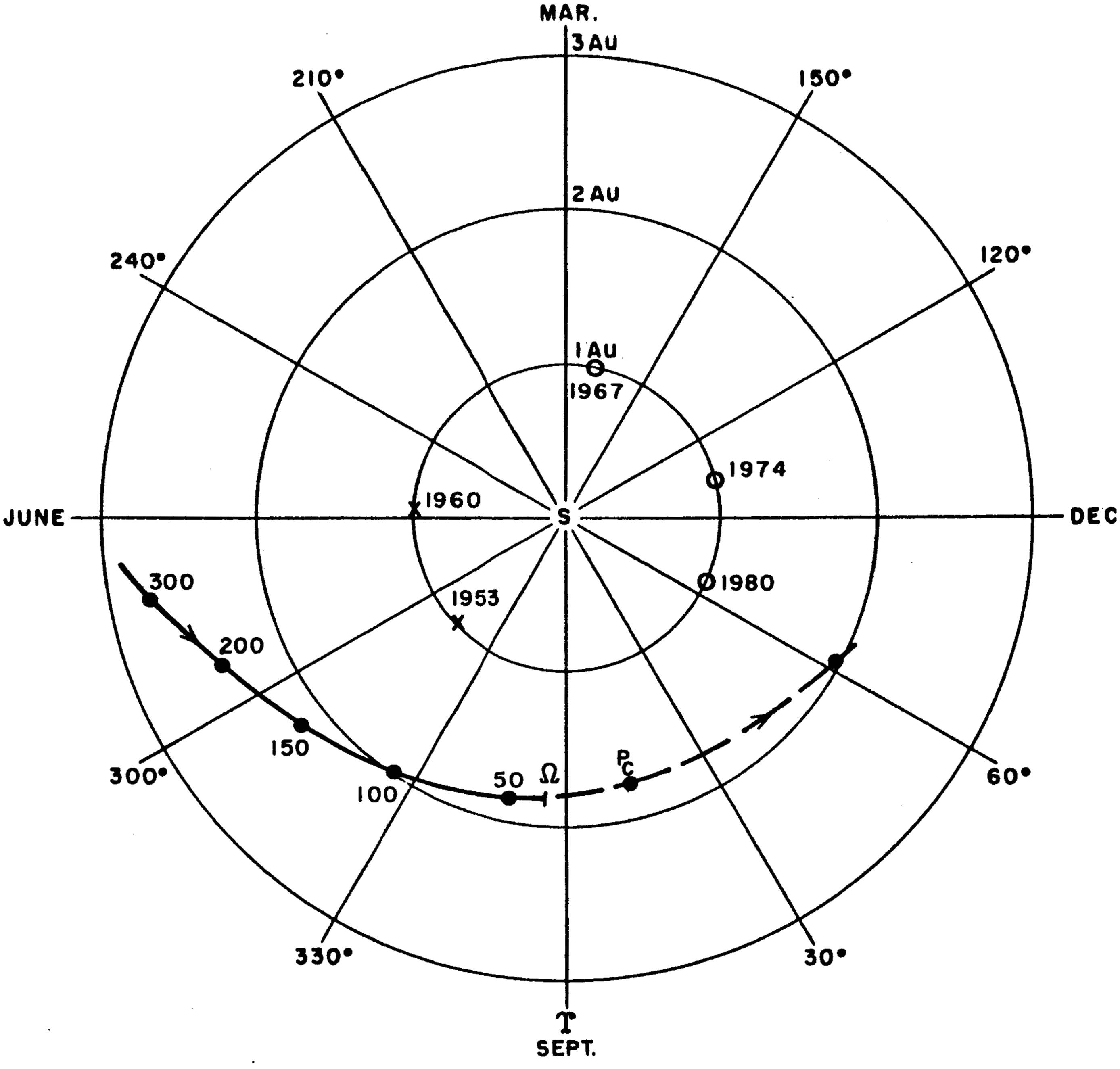
Tail   Usually an inconspicuous tail is associated with Brooks (2) being neither bright nor long. Strongest emission is CO^+ on a continuum.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
46 after	17.8	1.8 AU	Poor	17 Jun 60	---	Poor	180
50	18.5	1.8 AU	Fair	7 Aug 53	17.5	Fair	193

GENERAL COMMENTS: A faint comet which has been seen many times. Gradually having its eccentricity reduced and its period increased by Jupiter. The 1980 apparition will be the best in the next 25 years offering about 200 days recovery. However, it will be very faint at perihelion (mag 17) and therefore is not very suitable for a mission.

BROOKS 2



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PERIODIC COMET COMAS SOLA

HISTORICAL: Discovered in 1926 and observed at all four apparitions since. Although it moves out beyond the orbit of Jupiter its node is not far from the orbit and hence quite large perturbations are expected occasionally.

BRIGHTNESS: (See Section 2.4)

$$m = 8.5 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1961)

Period (P)	= 8.59 yrs	Eccentricity (e)	= 0.576
Semi-major axis (a)	= 4.19 AU	Long. asc. node (Ω)	= 62.8°
Inclination (i)	= 13.4°	Arg. perihelion (ω)	= 40°

PHYSICAL APPEARANCE:

Nucleus Almost stellar beyond 3 AU and remaining fairly well condensed throughout its apparition.

Coma A small round coma starts to form at about 2.5 AU from the Sun and remains through perihelion. It was as bright as 19.5 mag, 430 days before perihelion in 1951.

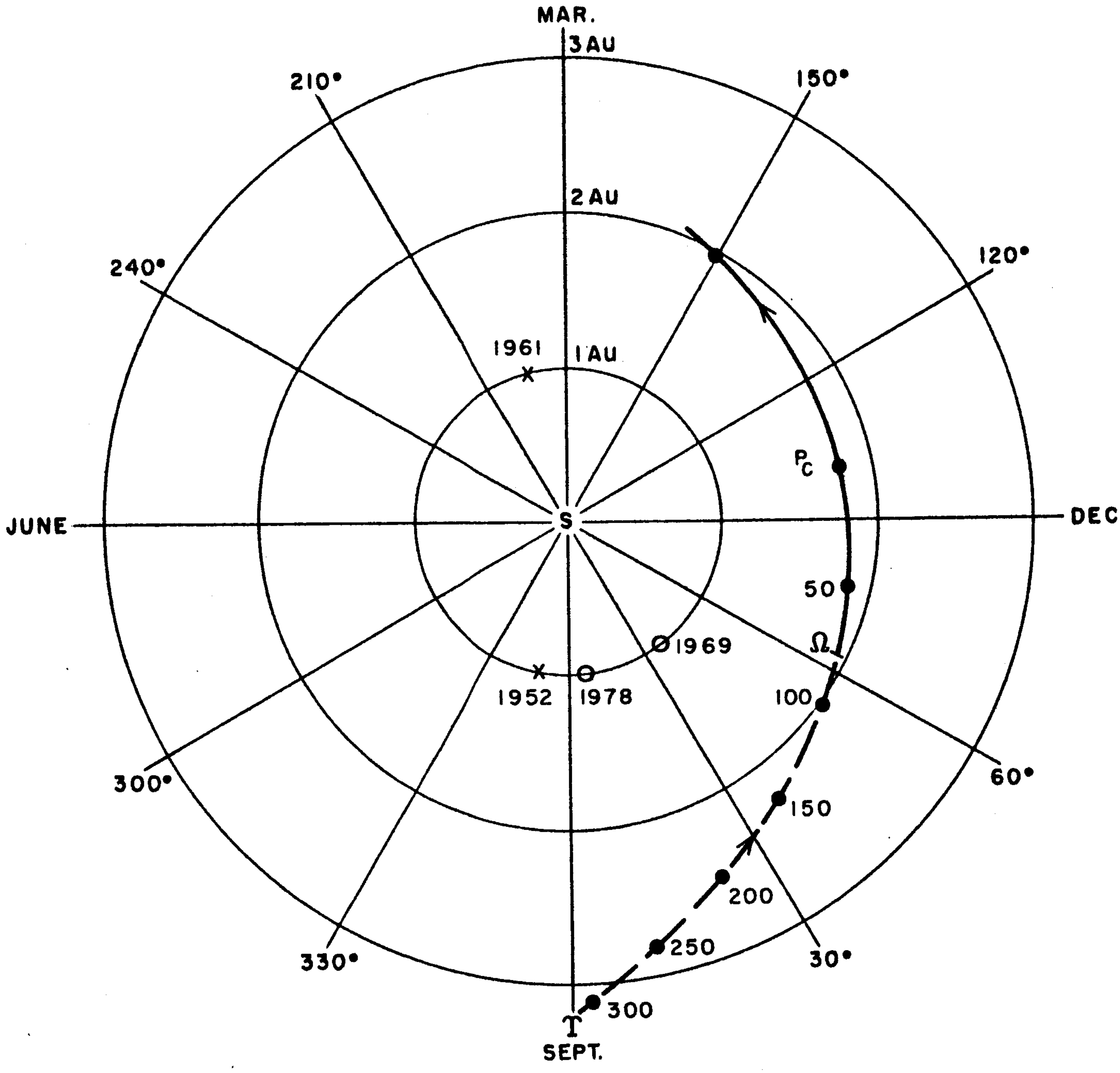
Tail A narrow but fairly well established tail has been seen on most apparitions within 200 days of perihelion.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
275	18.5	3 AU	Fair	4 Apr 61	16	Fair	650
430	19.5	> 3 AU	Good	10 Sep 52	13.5	Fair	380

GENERAL COMMENTS: Comas Sola is fairly faint due to its large solar distance but its orbit has been very well calculated. Very early recoveries are possible but of course the comet goes into conjunction with the Sun for a few months each observing year. The 1969 apparition should provide very early recovery (400 days) but the comet will be fairly faint at perihelion. This is the best passage during the next 25 years but is probably not good enough for consideration for a mission.

COMAS SOLA



P_C = PERIHELION OF COMET

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O = PREDICTED POSITIONS OF EARTH AT PERIHELION OF COMET (SEE SECT. 2·3)

PERIODIC COMET DANIEL

HISTORICAL: Discovered in 1909 and it has since been seen in 1937, 1943 and 1950. It was not seen in 1957 due to poor observing conditions. It was seriously perturbed in 1959 which will probably result in poor apparitions until it is further perturbed. It has a fairly high inclination.

BRIGHTNESS: (See Section 2.4)

$$m = 11.5 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1964)

Period (P)	= 7.09 yrs	Eccentricity (e)	= 0.550
Semi-major axis (a)	= 3.69 AU	Long. asc. node (Ω)	= 68.5°
Inclination (i)	= 20.13°	Arg. perihelion (ω)	= 10.97°

PHYSICAL APPEARANCE:

Nucleus Diffuse object at distances $>$ 2 AU and does not show any marked central condensation near perihelion.

Coma Diffuse fairly large round coma. Emission consists of a strong continuum with C_3, CN, CH and C_2.

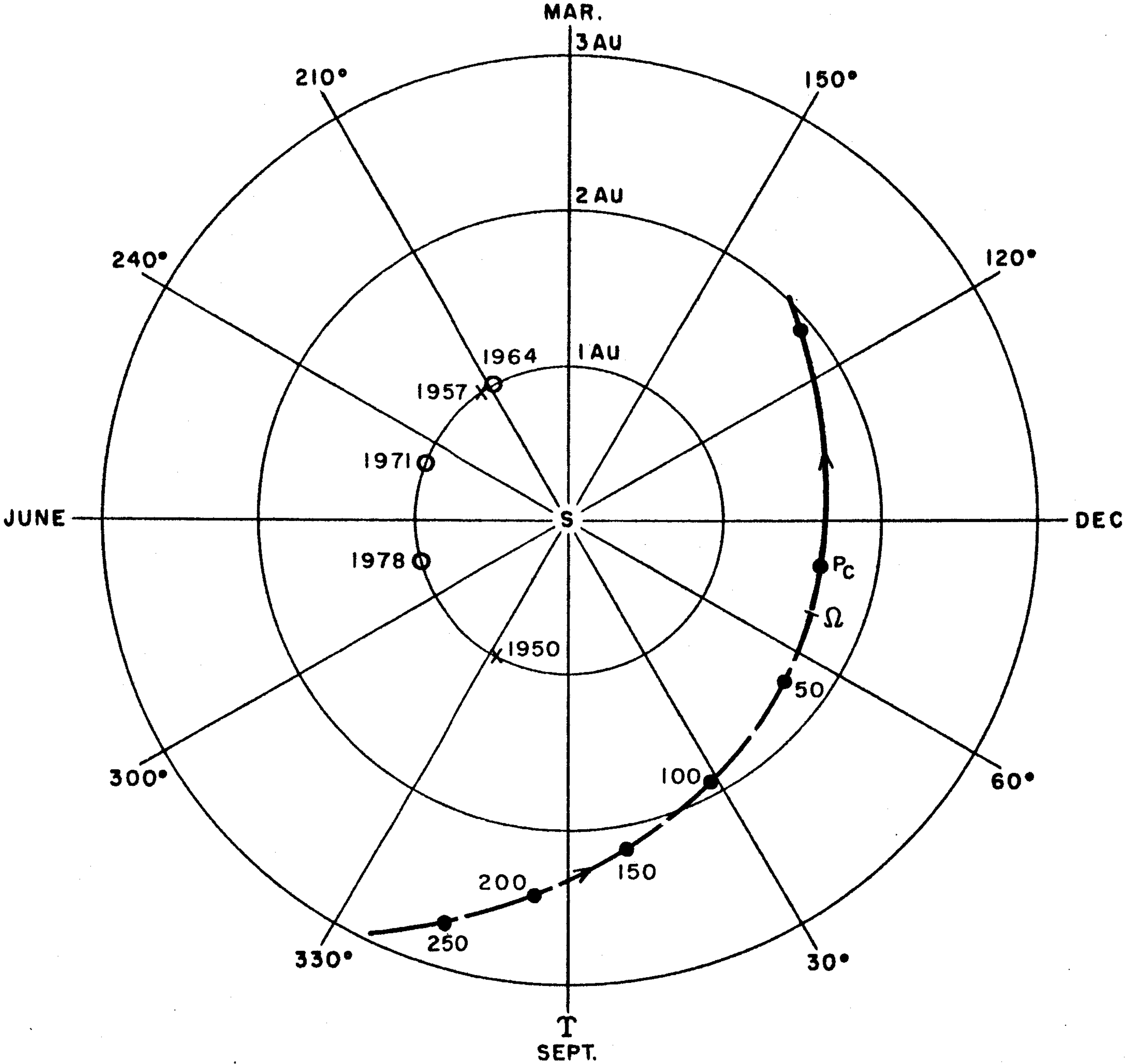
Tail Broad fairly well established tail (max mag 15) observed in 1950. Strong CO^+ lines observed.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
Not seen in	1957		Fair	25 Apr 57	--	Poor	--
1	16	1.5 AU	Good	24 Aug 50	16	Good	165

GENERAL COMMENTS: A fairly faint diffuse comet which has not been seen on a number of passages. It will probably not be seen at all in 1964. The passages in 1971 and 1978 will be unsuitably placed for recovery and observation at perihelion. Although scientifically interesting, its orbit makes it not worth considering for a mission in the next 25 years.

DANIEL



P_C = PERIHELION OF COMET

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PERIODIC COMET D'ARREST

HISTORICAL: Discovered in 1851 and seen at only 10 apparitions the last being in 1950. A large perturbation is expected in 1968 and the orbit shown represents the comet at its 1970 apparition when it approaches quite near the Earth's orbit.

BRIGHTNESS: (See Section 2.4)

$$m = 9.5 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1963)

Period (P)	=	6.67 yrs	Eccentricity (e)	=	0.614
Semi-major axis (a)	=	3.54 AU	Long. asc. node (Ω)	=	143.6°
Inclination (i)	=	18.1°	Arg. perihelion (ω)	=	174.5°

PHYSICAL APPEARANCE:

Nucleus Diffuse and ill-defined up to perihelion. Brightened and was well condensed about one month after perihelion and then return to obscurity in a further month (1950). Nucleus calculated to have a diameter $\simeq$ 3 km.

Coma A diffuse coma which grew considerably and brightened to mag 11 one month after perihelion in 1950. Observed at mag 19 at a distance of 2.8 AU from the Sun (1952).

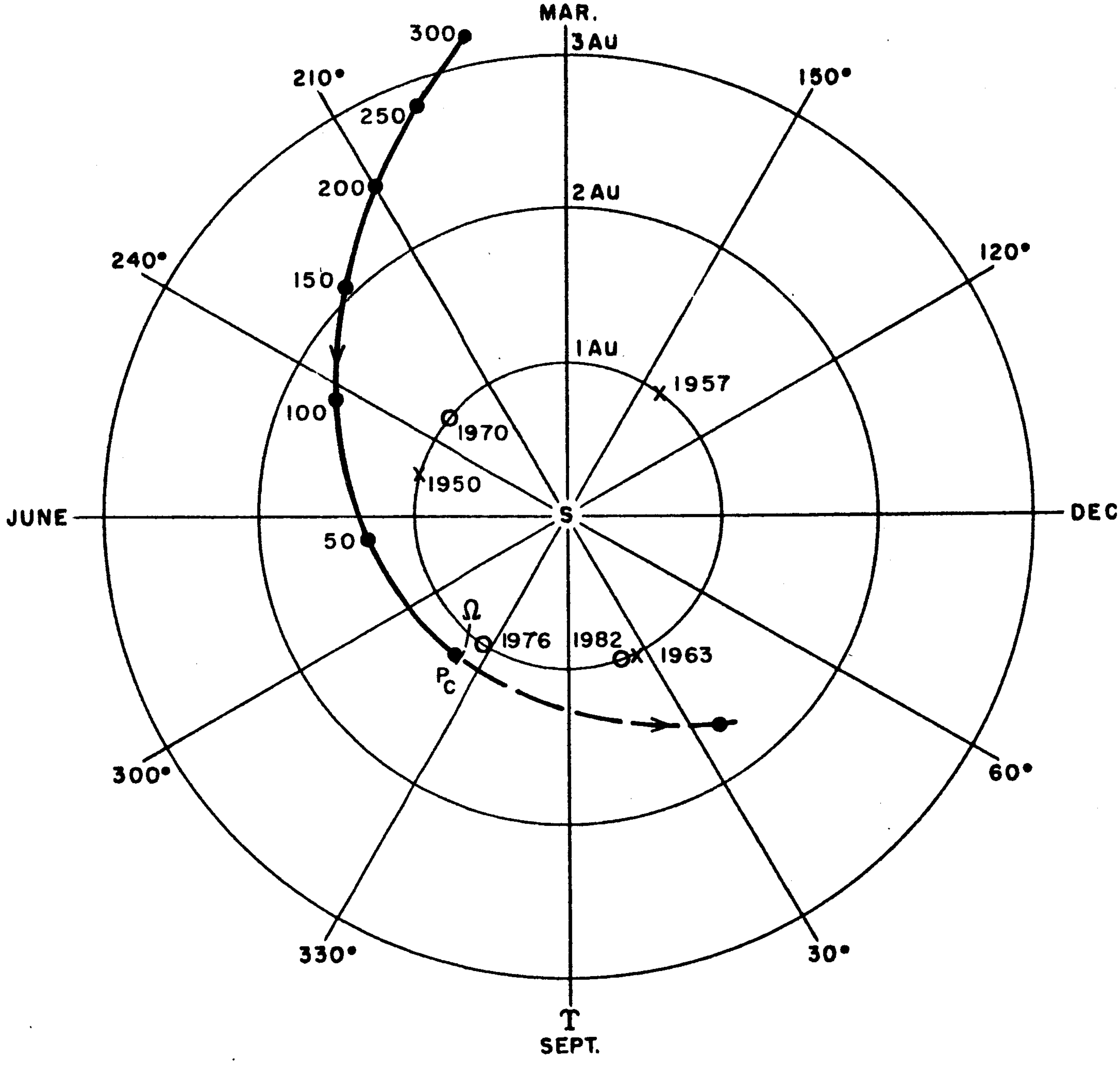
Tail A faint broad tail is suggested from observations.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
Not seen in	1957		Poor	13 Feb 57		Poor	--
47	18	1.5 AU	Fair	6 Jun 50	16	Fair	290

GENERAL COMMENTS: A diffuse comet which has brightened rapidly after perihelion. A mass loss of about 0.5% per passage is calculated from the established secular accelerations. The 1963 apparition should be quite good although very early recoveries are not expected with D'Arrest. Thereafter the 1976 passage will be much the most interesting with a chance of a 200 day recovery and good observation through perihelion. It should be considered for a mission.

D'ARREST



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PERIODIC COMET ENCKE

HISTORICAL: First observed in 1786 and has only been missed in 1944 in its 47 apparitions. It is reputed to have been in essentially its present orbit for 3000 yrs, losing 0.2% of its mass each revolution. It seems to lose one magnitude of brightness per century. It appears to be responsible for the Taurid permanent meteor shower.

BRIGHTNESS: (See Section 2.4)

$$m = 11.5 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1964)

Period (P)	= 3.30 yrs	Eccentricity (e)	= 0.847
Semi-major axis (a)	= 2.22 AU	Long. asc. node (Ω)	= 334°
Inclination (i)	= 11.9°	Arg. perihelion (ω)	= 186°

PHYSICAL APPEARANCE:

Nucleus Almost stellar up to 60 days before perihelion and beyond 100 days after perihelion. Diameter approx 3 km and the mass is calculated as 8×10^{16} gms. It is not certain if the nucleus is in a single piece.

Coma Gaseous coma starts to form some 100 days before perihelion. Although it grows quite large it is rather fuzzy. CN and C_2 emissions are particularly intense but no continuum is present.

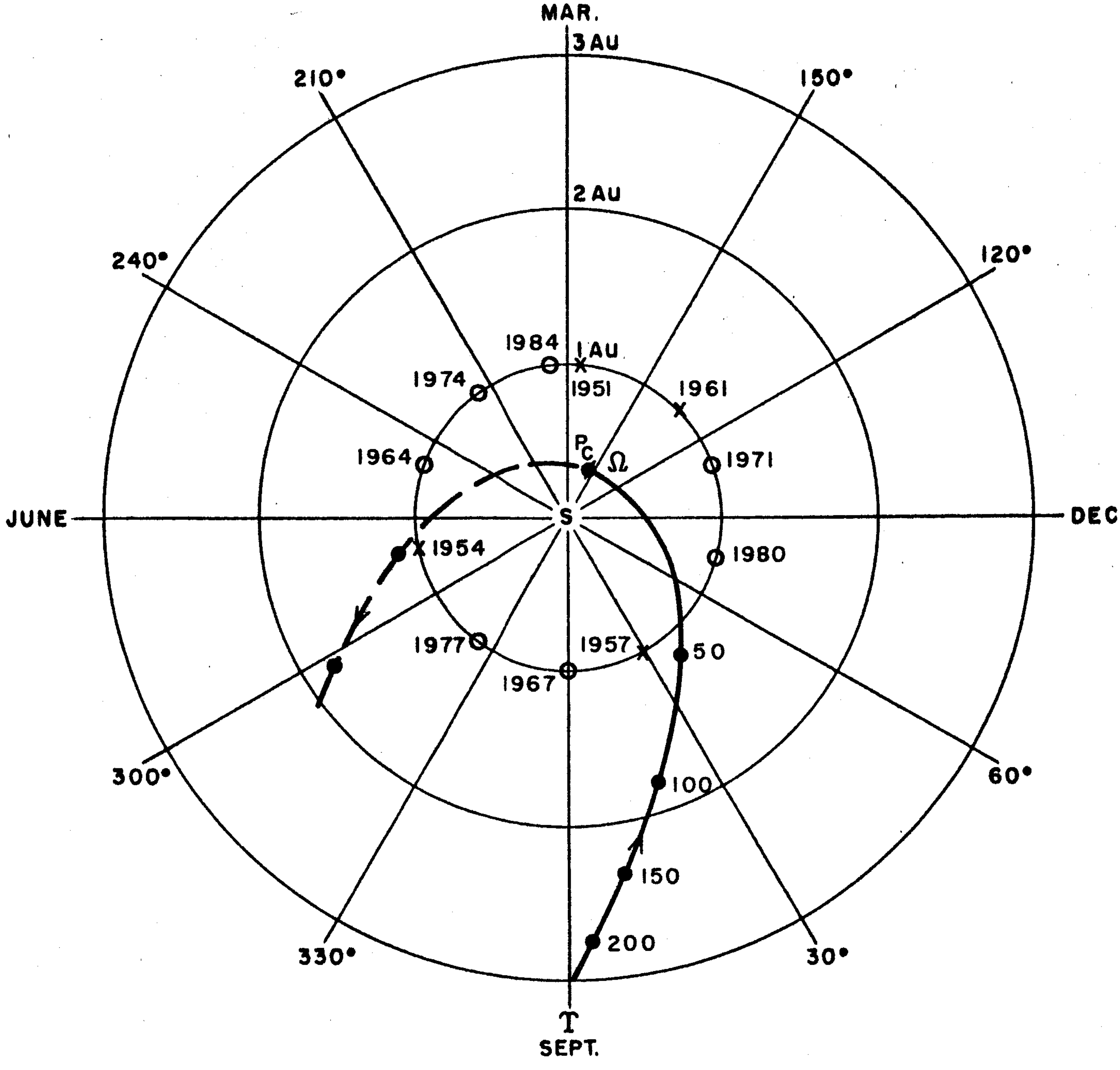
Tail A large gaseous tail usually accompanies Encke starting to form some 60 days before perihelion.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
178	19.5	2.5 AU	Good	5 Feb 61	--	Poor	164
87	18	1.6 AU	Fair	20 Oct 57	6	Poor	72
211	20	2.8 AU	Good	16 Mar 51	7.1	Poor	360

GENERAL COMMENTS: It is fairly bright at perihelion, its brightness varying almost as the cube of solar distance. It is subject to continuous slight perturbation but its orbit and the corrections required are well established. The spectrum shows CN and C_2 ($0.8 < r < 1$ AU) CN, C_2, CH and C_3 for $r > 1$ AU and for $r < .8$ AU. Encke is always difficult to observe at perihelion. It has been observed very many times and the present knowledge of Encke's comet makes it scientifically interesting for a mission. Good recoveries are expected in 1974 and 1984.

ENCKE



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PERIODIC COMET FAYE

HISTORICAL: Discovered in 1843 and observed at 15 returns, the last being in 1962. A large perturbation by Jupiter in 1959 was well calculated and the recovery in 1961 was very close to the prediction.

BRIGHTNESS: (See Section 2.4)

$$m = 11.1 + 10 \log \Delta + 5 \log r$$

ORBITAL PARAMETERS: (1962)

Period (P)	=	7.38 yrs	Eccentricity (e)	=	0.576
Semi-major axis (a)	=	3.79 AU	Long. asc. node (Ω)	=	199°
Inclination (i)	=	9.09°	Arg. perihelion (ω)	=	203°

PHYSICAL APPEARANCE:

Nucleus — Nucleus is almost stellar at distances greater than 2 AU. Generally well condensed before perihelion.

Coma — A fairly faint coma reaching about 2×10^4 km diameter. The maximum brightness is before perihelion.

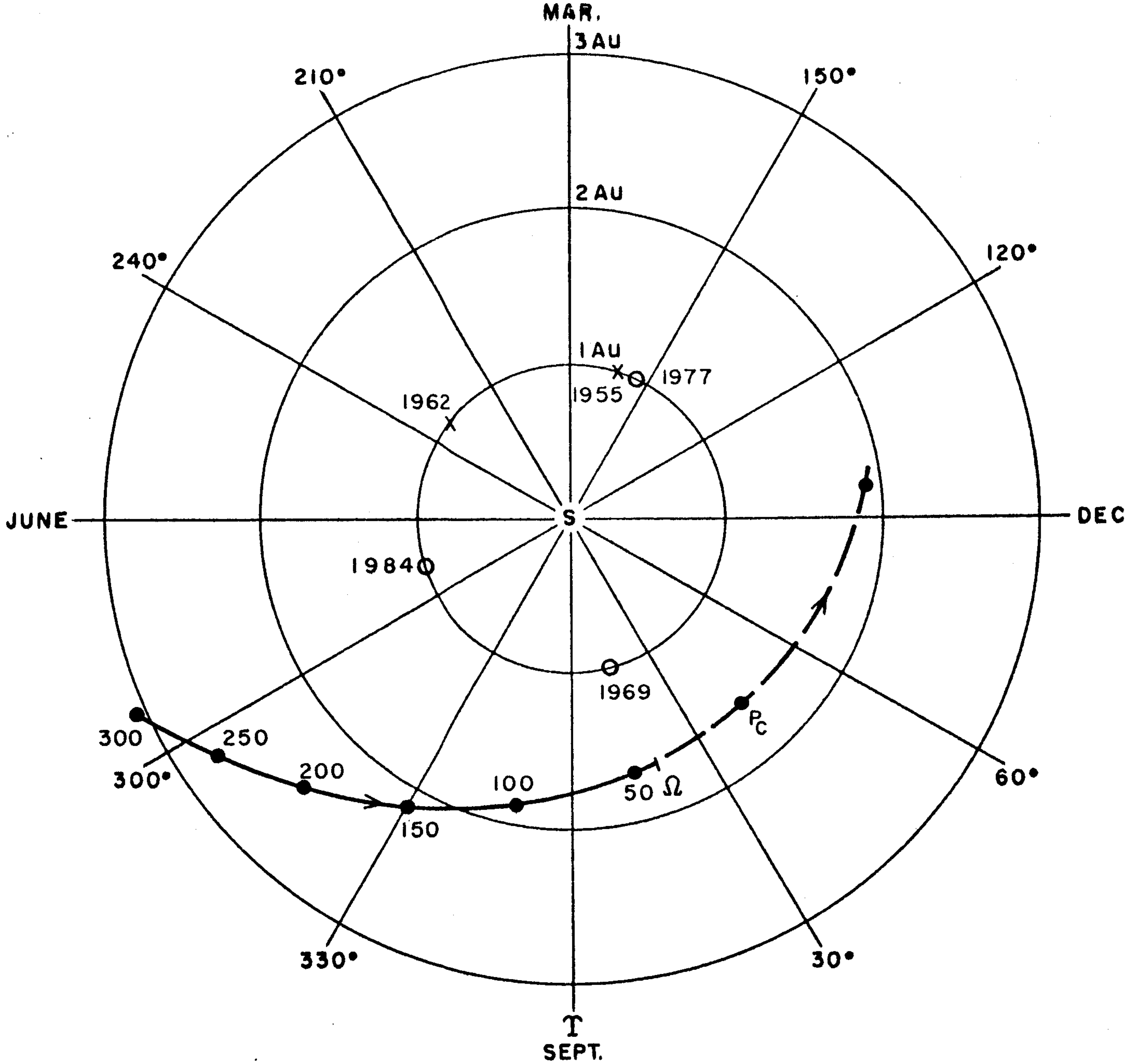
Tail — A short fuzzy tail is associated with Faye.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
310	19.8	3 AU	V. good	14 May 62	--	V. poor	350
230	17	2.6 AU	Good	3 Mar 55	15	Fair	390

GENERAL COMMENTS: The brightness of Faye appears to be decreasing by about 1 mag per decade (mag 9.6 in 1932). It has been observed 1 year each side of perihelion but was in conjunction with the Sun just after perihelion in 1955 and just before in 1962. No spectroscopic data is available. The apparition in 1969 will be the brightest (mag 12) and recovery of 150 days can be expected. Even in 1969 it will be of only moderate scientific interest.

FAYE



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PERIODIC COMET FINLAY

HISTORICAL: Discovered in 1886 it has been observed 7 times, the latest being 1926, 1953 and 1960. It is subject to slight perturbations by Jupiter. Secular changes have caused a recession of the nodes, the ascending node changing from 53.2 to 42.1° since 1886.

BRIGHTNESS: (See Section 2.4)

$$m = 11.5 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1960)

Period (P)	= 6.90 yrs	Eccentricity (e)	= 0.703
Semi-major axis (a)	= 3.61 AU	Long. asc. node (Ω)	= 42.1°
Inclination (i)	= 3.6°	Arg. perihelion (ω)	= 321.6°

PHYSICAL APPEARANCE:

Nucleus Centrally condensed near perihelion.

Coma Round medium sized diffuse coma which shows condensation near perihelion.

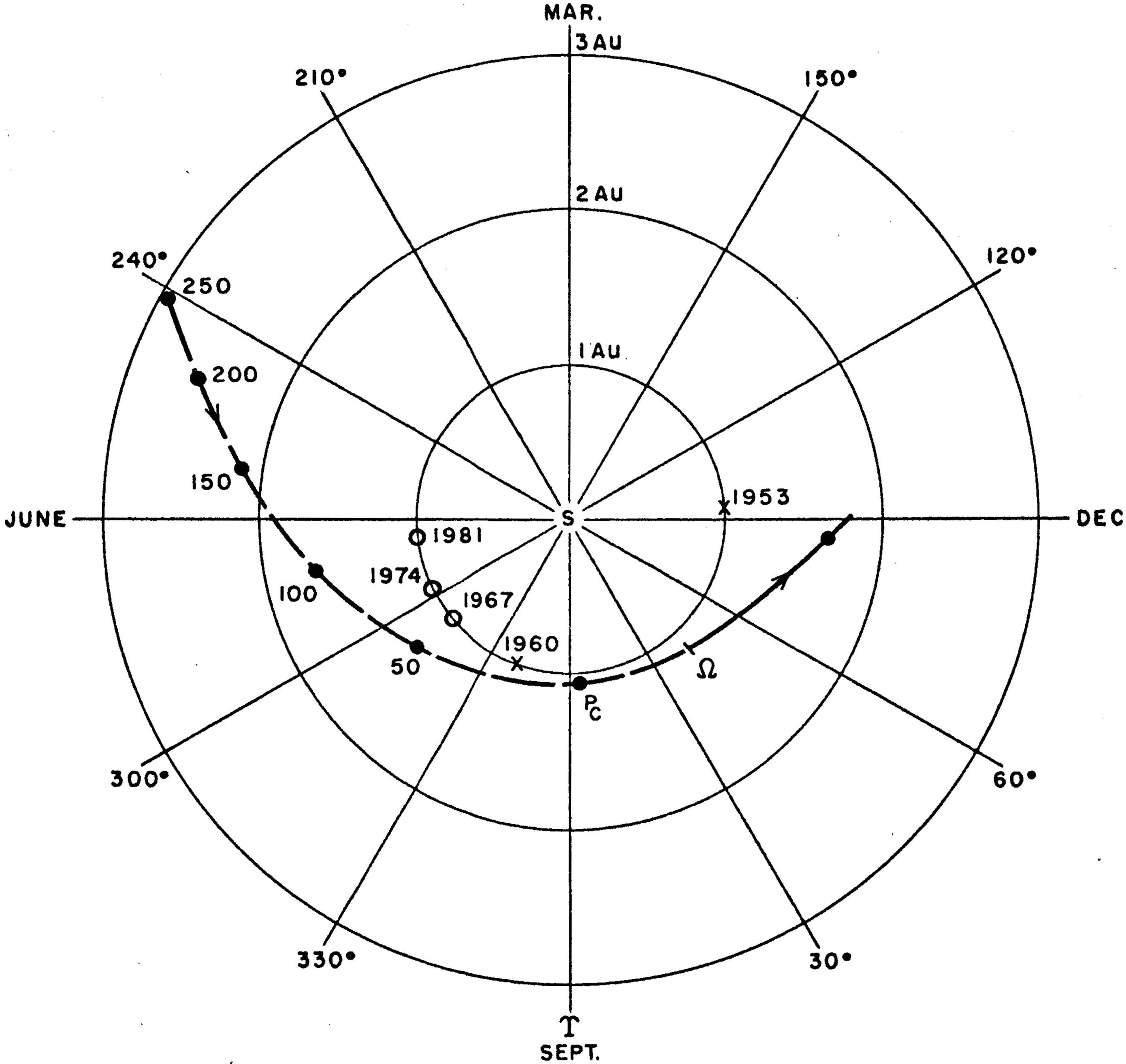
Tail Only a faint trace of a tail has been observed.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
72	16	1.5 AU	F. good	1 Sep 60	11	Good	200
10	10.5	1.1 AU	Fair	25 Dec 53	10	Fair	110

GENERAL COMMENTS: A generally diffuse but fairly bright comet. Sighting problems from the northern hemisphere may make early recovery difficult for the 1967, 1974, and 1981 apparitions. Observation at perihelion and the recovery time will get progressively worse during the century. This is not a good comet for consideration for a mission in the next 25 years.

FINLAY



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PERIODIC COMET FORBES

HISTORICAL: Discovered in 1929 and has been observed in 1942, 1948 and 1961. Poor observing conditions prevented it being seen in 1955 and may again in 1967. It will suffer a fairly large perturbation in 1978.

BRIGHTNESS: (See Section 2.4)

$$m = 11.3 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1961)

Period (P)	= 6.42 yrs	Eccentricity (e)	= 0.553
Semi-major axis (a)	= 3.45 AU	Long. asc. node (Ω)	= 25.4°
Inclination (i)	= 4.6°	Arg. perihelion (ω)	= 259.7°

PHYSICAL APPEARANCE:

Nucleus Well defined strong central condensation near perihelion. Nearly stellar at distances greater than 2 AU.

Coma Fairly small diffuse coma is usual. It has been observed at a distance of 2.5 AU at magnitude 20.

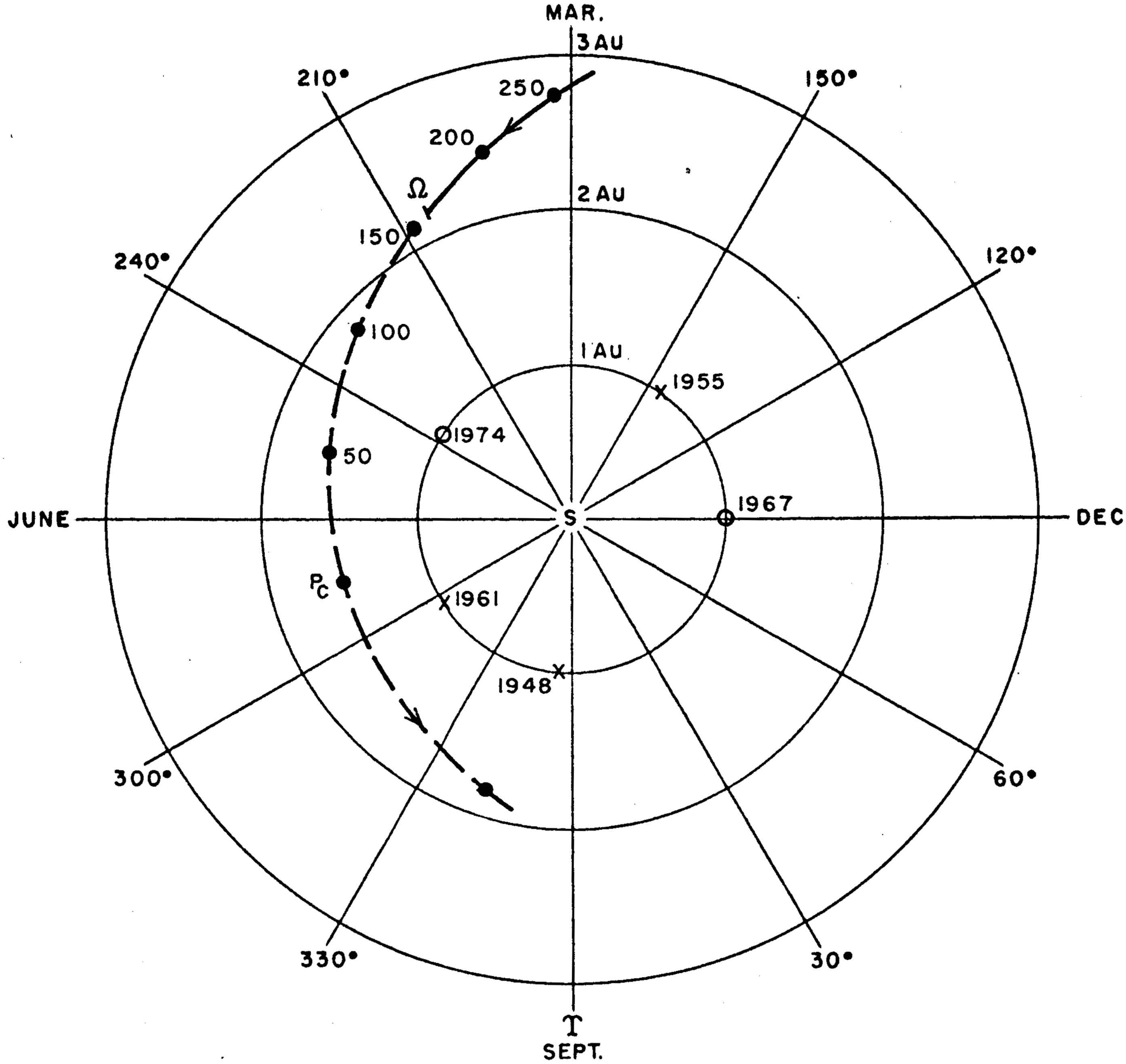
Tail Faint narrow tail was observed in 1961.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
190	20	2.5 AU	V. Good	24 Jul 61	14.5	V. Good	320
Not seen in	1955		Poor	17 Feb 55	---	Poor	
120	17	1.9 AU	Good	16 Sep 48	14.5	Fair	130

GENERAL COMMENTS: A fairly faint comet for which there is no spectroscopic data. Observations from the northern hemisphere were difficult near perihelion in 1961 and will be in 1974. However good recovery (180 days) is expected for the 1974 passage which will be the best apparition before 1980. However, the comet will be faint at perihelion and probably not suitable for an intercept mission.

FORBES



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PERIODIC COMET GIACOBINI-ZINNER

HISTORICAL: It has been seen 7 times since 1900 and is noted for the periodic meteor shower (Giacobinids) when it passes close to the Earth. Not observed in 1954 due to poor sighting conditions. It was perturbed by Jupiter in 1956 but then well observed in 1959.

BRIGHTNESS: (See Section 2.4)

$$m = 11.5 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1959)

Period (P)	= 6.42 yrs	Eccentricity (e)	= 0.724
Semi-major axis (a)	= 3.45 AU	Long. asc. node (Ω)	= 196°
Inclination (i)	= 30.9°	Arg. perihelion (ω)	= 173°

PHYSICAL APPEARANCE:

Nucleus Usually well condensed throughout its apparition. Diameter 0.5 - 4.5 km estimated when it passed close to the Earth in 1959. Largely dust nucleus.

Coma Generally small concentrated coma. Emission principally a continuum (i.e., dust) and CN ($\sim 10^2$ mols/cm^3) is much more intense than C_2 emission.

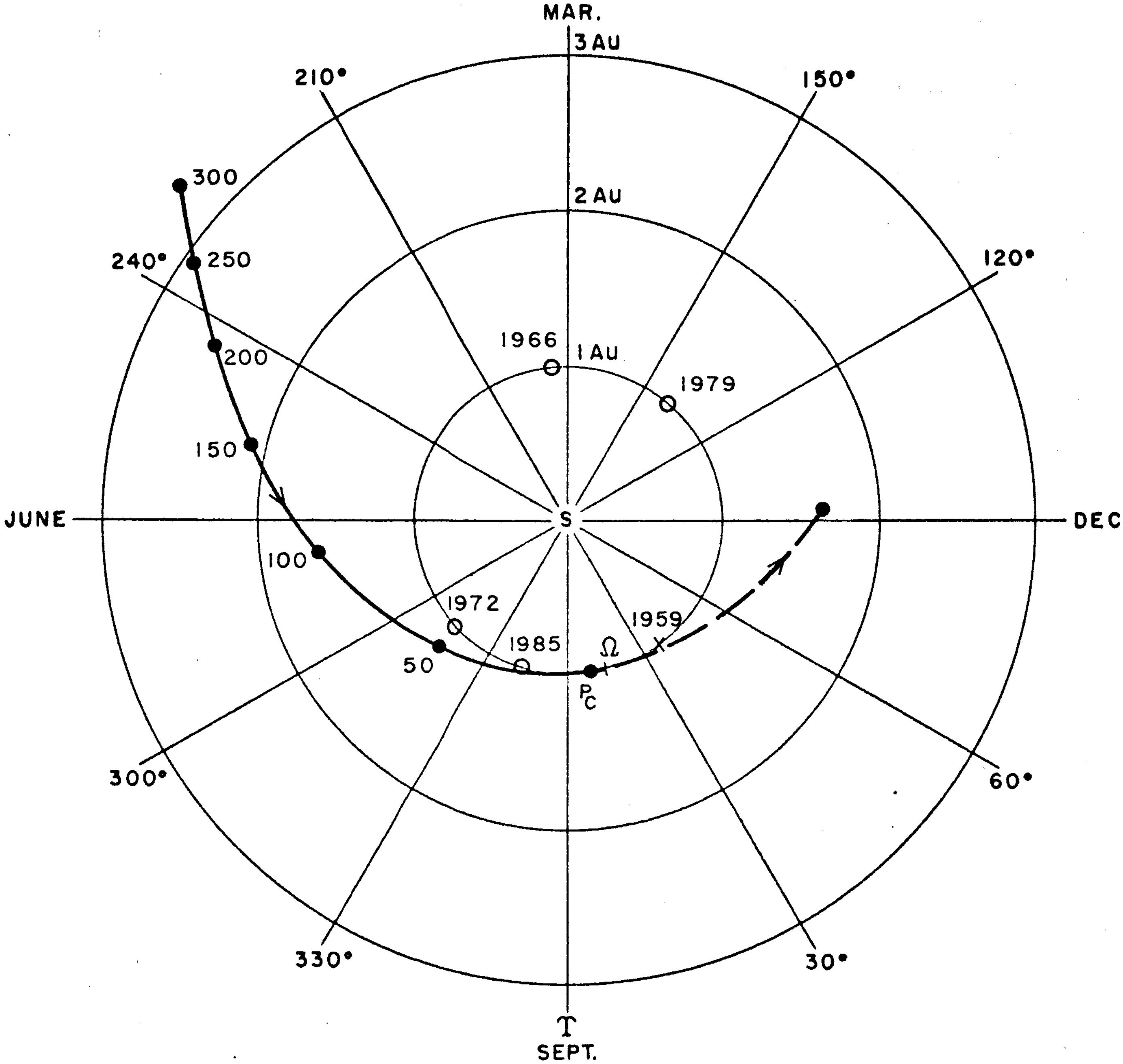
Tail A dusty type tail has been detected 100 days before perihelion (r = 1.7 AU) and to develop well. It has been observed up to 100 days after perihelion.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
170	20	2.4 AU	V. good	26 Oct 59	7	Good	325
Not seen in	1954		Poor			Poor	

GENERAL COMMENTS: One of the brightest periodic comets when it is close to the Earth. Its relatively high inclination gives it a rapid motion near perihelion and it is sometimes not observable from the northern hemisphere after perihelion. The 1972 and the 1985 apparitions should be good for recovery, brightness and observation through perihelion. It will make an interesting scientific target at these apparitions. Continual perturbation will move perihelion just outside the Earth's orbit by 1985.

GIACOBINI-ZINNER



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PERIODIC COMET GRIGG-SKJELLERUP

HISTORICAL: Discovered in 1902 and next observed in 1922. It has been observed at each apparition since but observation conditions have been poor for the past few appearances. It is subject to a large perturbation in 1964 and the orbit is plotted for the next passage in 1967.

BRIGHTNESS: (See Section 2.4)

$$m = 13.4 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1961)

Period (P)	= 4.91 Yrs	Eccentricity (e)	= 0.703
Semi-major axis (a)	= 2.88 AU	Long. asc. node (Ω)	= 215.4°
Inclination (i)	= 17.6°	Arg. perihelion (ω)	= 356.3°

PHYSICAL APPEARANCE:

Nucleus A sharp condensation was observed some 40 days before perihelion in 1961.

Coma A diffuse coma which becomes faintly observable about one month before perihelion.

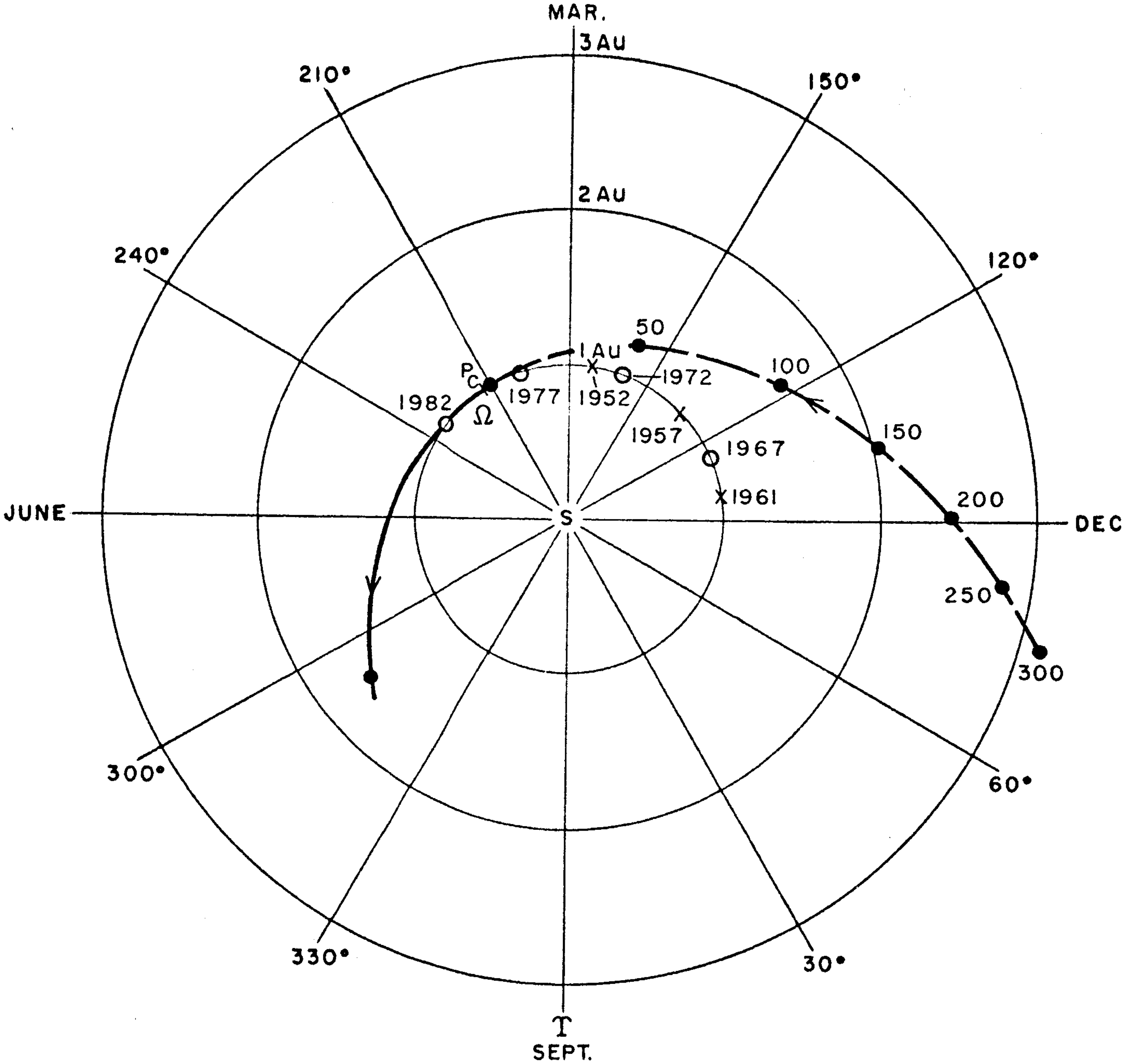
Tail A very fuzzy short tail has been seen.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
53	18	1.2 AU	Fair	31 Dec 61	15	Poor	55
33	14	1 AU	Fair	2 Feb 57	--	Fair	10
5	12	0.86 AU	Fair	11 Mar 52	12	Fair	50

GENERAL COMMENTS: Grigg-Skjellerup is a faint comet which is often difficult to observe from the northern hemisphere due to its fairly large inclination. It brightens very rapidly and is seldom visible more than 100 days before perihelion. An excellent opportunity for observation of the comet and for an intercept mission is presented in 1977. The 1982 apparition will also be quite good.

GRIGG-SKJELLERUP



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PERIODIC COMET HALLEY

HISTORICAL: Recorded appearances date back to 239 B.C. and although every apparition has been observed, the last of the three predicted returns was in 1910. On that passage it was extensively studied on a world wide basis. Its retrograde motion is unusual in periodic comets. A link has been suggested with the permanent meteor showers Orinids and Aquarids.

BRIGHTNESS: (See Section 2.4)

A very bright comet

ORBITAL PARAMETERS: (1910)

Period (P)	= 76.02 yrs	Eccentricity (e)	= 0.967
Semi-major axis (a)	= 17.8 AU	Long. asc. node (Ω)	= 57.8°
Inclination (i)	= 162.2°	Arg. perihelion (ω)	= 111.7°

PHYSICAL APPEARANCE:

Nucleus Less than 50 km dia and much less than 10^{-10} times the Earth mass. There is no evidence for rotation or oscillation of the nucleus. On many occasions secondary nuclei have been observed and explosive reactions seen to occur. There is apparently no permanent form to the nucleus. Main emissions are a continuum, CN and C_2.

Coma Well formed fairly stable coma (dia $> 3 \times 10^5$ km) exhibiting straight jets. The minimum coma size occurs about 6 weeks before perihelion. Main emissions are CN, C_2 and CH bands superimposed on a continuum.

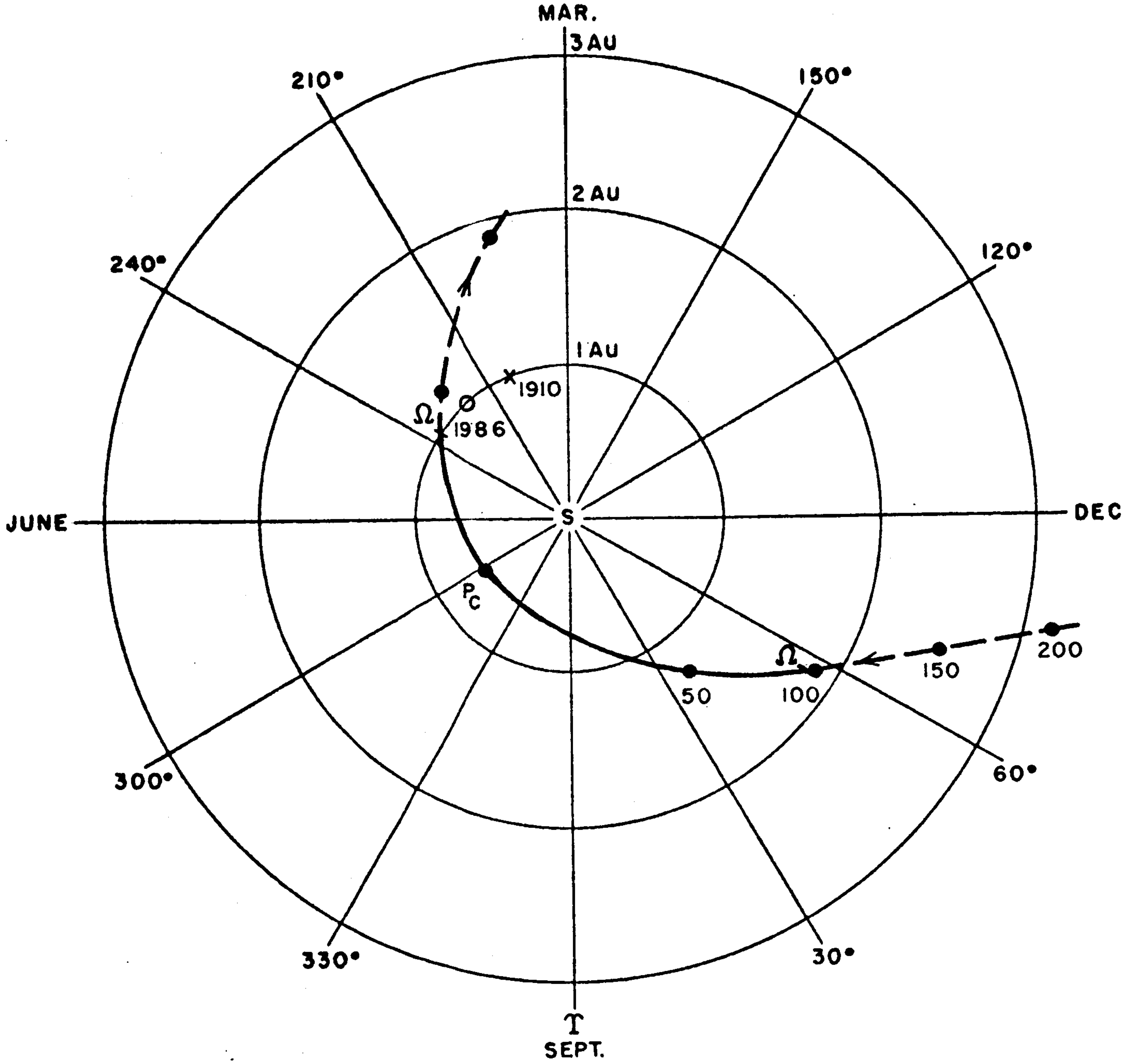
Tail Two well developed tails were observed in 1910. One primarily gaseous (CN, CO^+) and the other mainly dust. Max length $> 10^7$ km and they stayed in the plane of the orbit.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
240	15	3.6 AU	Good	19 Apr 10	1	Good	656

GENERAL COMMENTS: A comet easily visible with the naked eye and brightest just after perihelion. The nucleus emits both dust and gas molecules quite profusely when near the Sun. A great deal of physical data exists for Halley which is excellently reported by Bobrovnikoff in Lick Obs. Publications No. 17, 1931. Halley's comet will be an object of immense interest on its next predicted return in 1986 when the Earth will be in a good position for an intercept mission.

HALLEY



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PERIODIC COMET HARRINGTON

HISTORICAL: Discovered just before perihelion in 1953. Again seen in 1960 but only after perihelion. Thus it has not been well observed up to the present.

BRIGHTNESS: (See Section 2.4)

ORBITAL PARAMETERS: (1960)

Period (P)	= 6.80 yrs	Eccentricity (e)	= 0.559
Semi-major axis (a)	= 3.59 AU	Long. asc. node (Ω)	= 119.2°
Inclination (i)	= 8.7°	Arg. perihelion (ω)	= 232.8°

PHYSICAL APPEARANCE:

Nucleus No marked central condensation has been observed.

Coma A small coma which has been well defined but faint near perihelion.

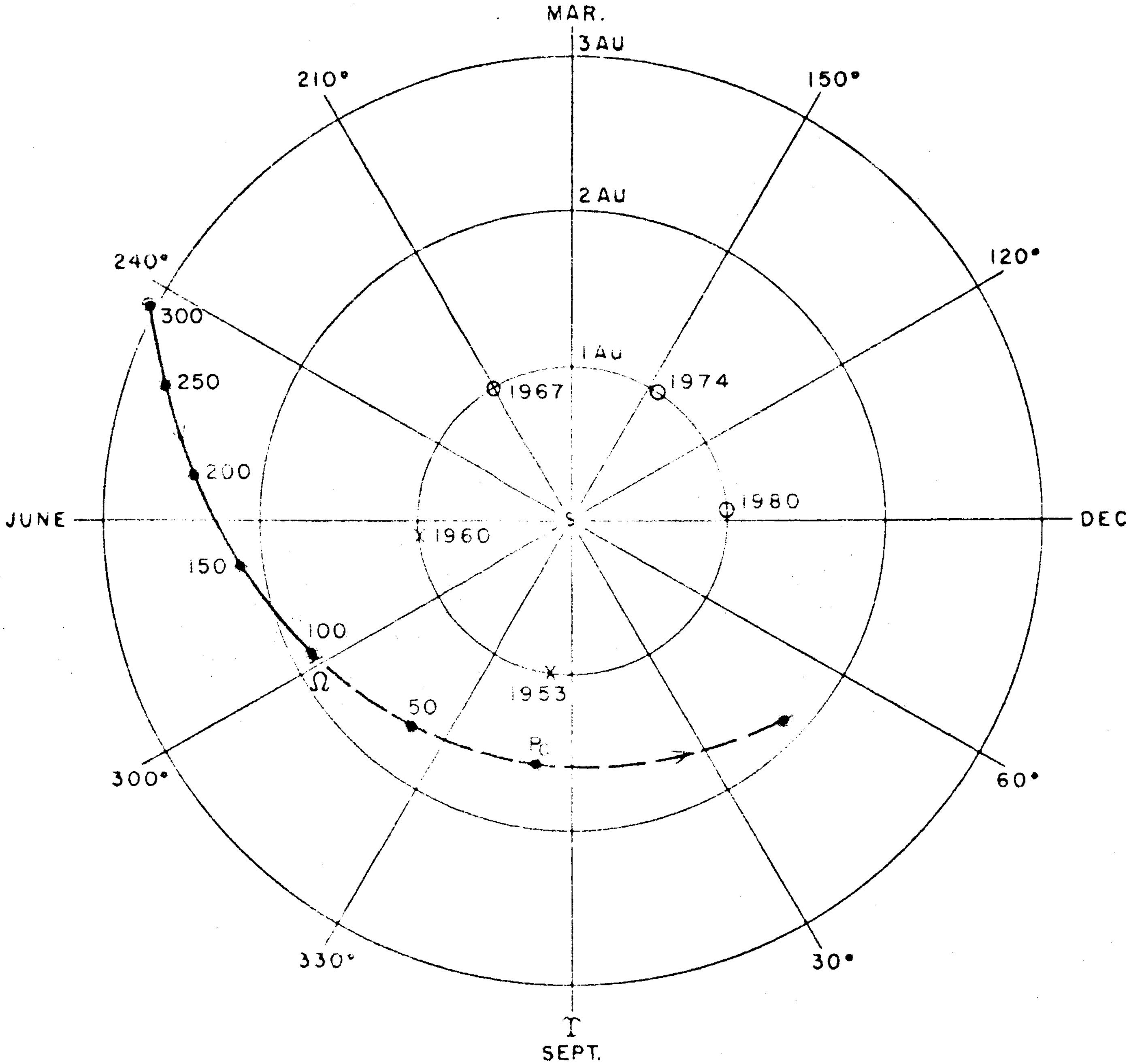
Tail Very faint fairly short tail near perihelion.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
36 after	19	1.6 AU	Fair	28 Jun 60	--	Good	60
20	15	1.6 AU	Discovered	22 Sep 53	15	Good	100

GENERAL COMMENTS: A very faint comet which has only been observed near perihelion. Its magnitude was only 15 when in opposition at perihelion in 1953. An early recovery cannot be expected on the basis of the brightness of the two previous apparitions. None of the 1967, 1974, or 1980 apparitions will offer good sighting at or near perihelion and therefore Harrington is not considered a good target for an intercept mission.

HARRINGTON



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PERIODIC COMET HARRINGTON-ABELL

HISTORICAL: Discovered in 1955 and observed again in 1962 being its first predicted return. Its node is relatively near the orbit of Jupiter which will perturb its orbit considerably in 1974 changing its inclination from 16° to 10° and increasing its period. The 1969 orbit has been plotted.

BRIGHTNESS: (See Section 2.4)

$$m = 12 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1962)

Period (P)	= 7.24 yrs	Eccentricity (e)	= 0.523
Semi-major axis (a)	= 3.74 AU	Long. asc. node (Ω)	= 145.9°
Inclination (i)	= 16.80°	Arg. perihelion (ω)	= 338.29°

PHYSICAL APPEARANCE:

Nucleus Faint but strongly condensed near perihelion. Almost stellar beyond 2 AU from the Sun.

Coma Only a small diffuse coma has been associated with Harrington-Abell.

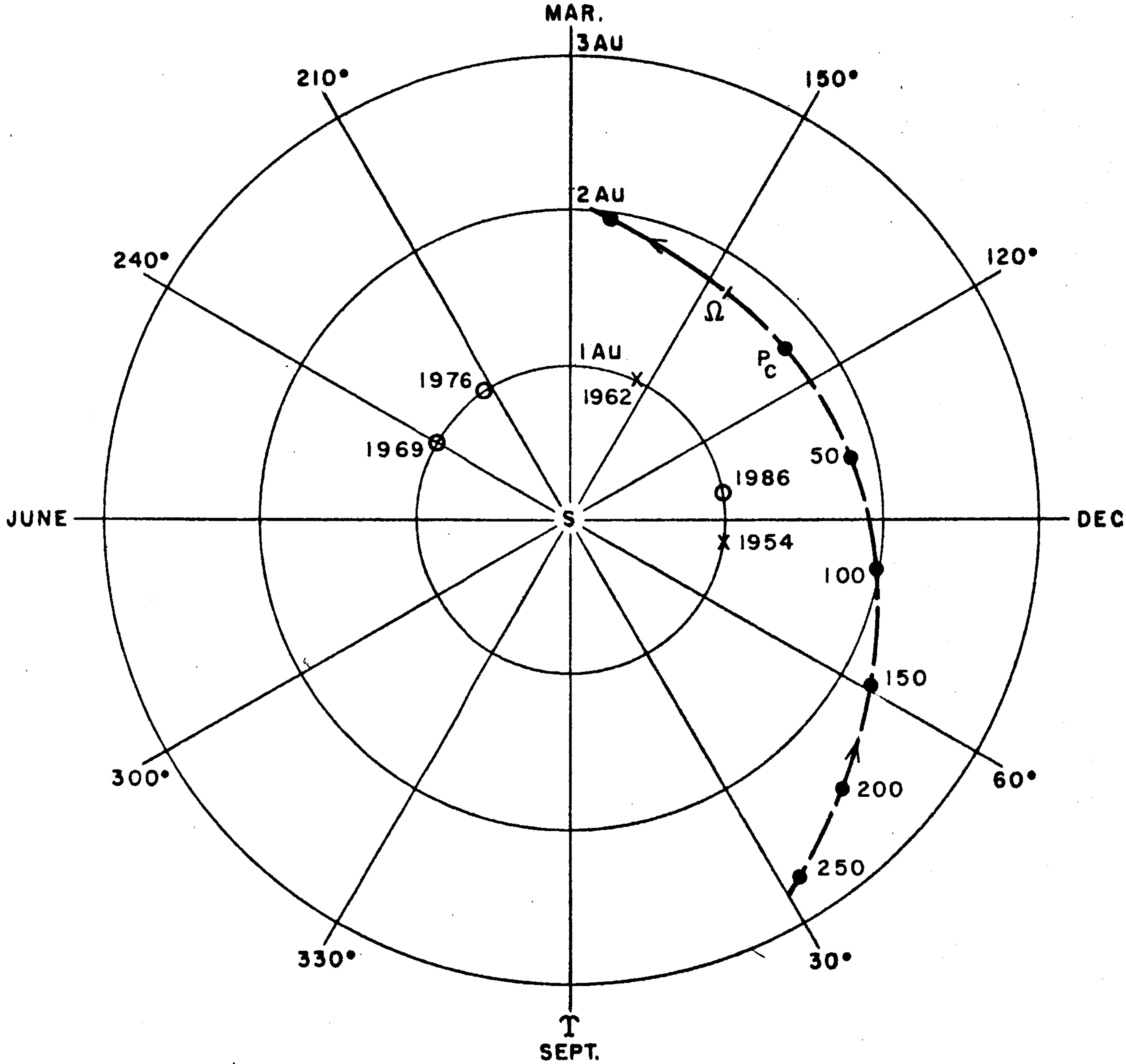
Tail A trace of a tail has been observed.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
30	17.8	1.8 AU	Good	24 Feb 62	17.5	Good	90
98 after	18	2 AU	Discovered	13 Dec 54	--	--	60

GENERAL COMMENTS: Very faint diffuse comet which has only been observed for a total of 150 days in its two apparitions. Despite its relatively large inclination it can usually be observed from the northern hemisphere. The comet will be entering conjunction with the Sun at perihelion in 1969 and 1976. The 1986 apparition will be the best in the period considered but perturbations will have increased the perihelion distance to 2.3 AU by then making the comet even fainter.

HARRINGTON - ABELL



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PERIODIC COMET HONDA-MRKOS-PAJDUSAKOVA

HISTORICAL: Discovered in 1948 independently by three observers. It was seen in 1954 but not in 1959 due to poor observation conditions. A weak connection seems to exist with the δ– aquarid permanent meteor shower.

BRIGHTNESS: (See Section 2.4)

$$m = 14.1 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1964)

Period (P)	= 5.21 yrs	Eccentricity (e)	= 0.815
Semi-major axis (a)	= 3.00 AU	Long. asc. node (Ω)	= 233.13°
Inclination (i)	= 13.2°	Arg. perihelion (ω)	= 184.13°

PHYSICAL APPEARANCE:

Nucleus Generally weak diffuse nucleus.

Coma Very diffuse but fairly large coma ($\simeq 4 \times 10^4$ km). Little central condensation.

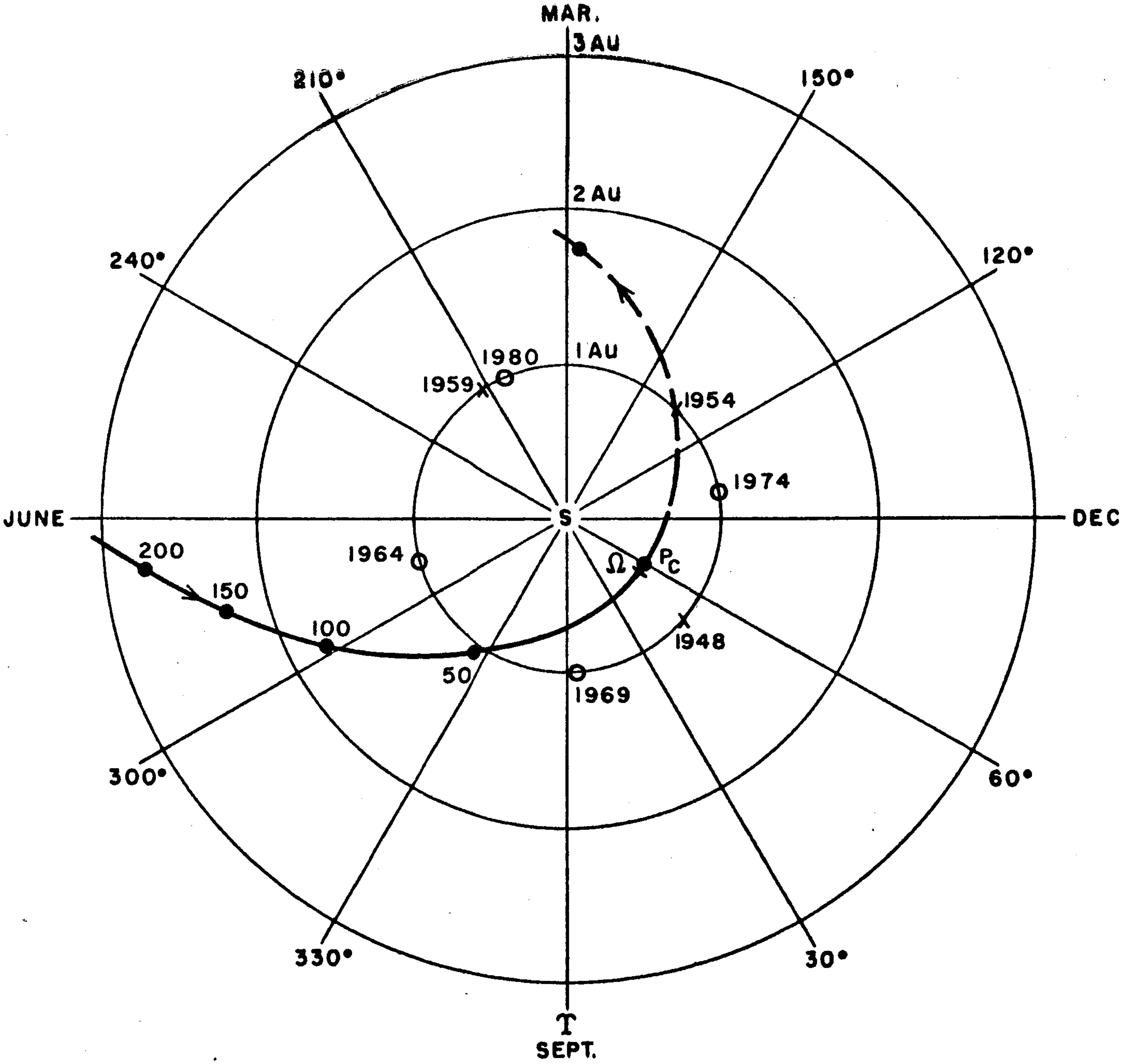
Tail Only a faint and poorly defined tail has been observed.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
Not seen in	1959		Poor	23 Apr 59	--	Poor	
1	10	1.5 AU	Good	5 Feb 54	--	Good	63
16 after	9	0.6 AU	Discovered	17 Nov 48	--	Fair	35

GENERAL COMMENTS: This is a fairly faint comet which fades quite rapidly. It has only been observed after perihelion so far. Observing conditions for recovery were good in 1953 but the elements were not well known - hence the poor recovery. 1974 should be good for recovery (180 days) and fairly good for observation up to perihelion after which it will pass in front of the Sun. It will suffer a fairly large perturbation in 1983. This comet is not sufficiently known or well placed for consideration for a comet intercept mission before 1985.

HONDA-MRKOS-PAJDUSAKOVA



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PERIODIC COMET JOHNSON

HISTORICAL: Discovered in 1949 and observed in 1955 and 1963. It is subject to occasional perturbation by Jupiter despite its fairly high inclination.

BRIGHTNESS: (See Section 2.4)

$$m = 8.5 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1963)

Period (P)	= 6.86 yrs	Eccentricity (e)	= 0.377
Semi-major axis (a)	= 3.61 AU	Long. asc. node (Ω)	= 118.16°
Inclination (i)	= 13.87°	Arg. perihelion (ω)	= 205.93°

PHYSICAL APPEARANCE:

Nucleus — Usually sharply condensed near perihelion.

Coma — A small diffuse coma surrounds the central condensation.

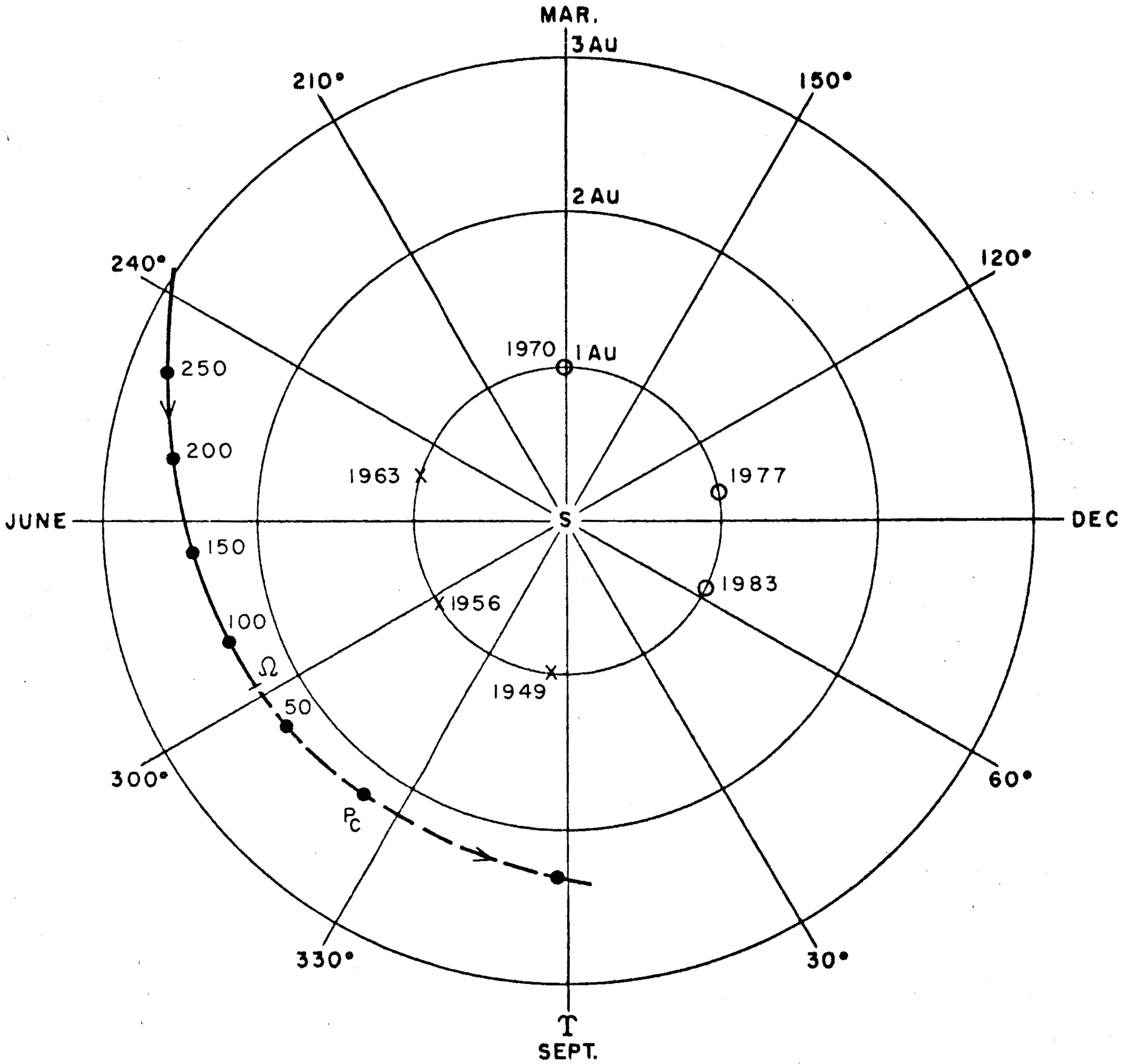
Tail — Only a trace of a tail has been detected.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
42	18.5	2.5 AU	Fair	6 Jun 63	?	Fair	?
11 after	13.5	2.27 AU	Good	26 Jul 56	--	Good	75
23	14	2.3 AU	Discovered	16 Sep 49	16	Good	60

GENERAL COMMENTS: A faint comet which is often difficult to observe from the northern hemisphere. Its orbit is now becoming better known but recovery is sometimes complicated by conjunction with the Sun because of the large orbit and relatively small eccentricity. The comet will not be suitably placed for observation at perihelion in 1970, 1977 or 1983. It is therefore not worth considering for an intercept mission.

JOHNSON



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PERIODIC COMET KOPFF

HISTORICAL: Discovered in 1906 and observed in each apparition after 1912. It was not observed until well after perihelion in 1958 due to poor observation conditions. It was extensively perturbed by Jupiter in 1954.

BRIGHTNESS: (See Section 2.4)

$$m = 8.5 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1964)

Period (P)	= 6.32 yrs	Eccentricity (e)	= 0.556
Semi-major axis (a)	= 3.42 AU	Long. asc. node (Ω)	= 121°
Inclination (i)	= 4.71°	Arg. perihelion (ω)	= 162°

PHYSICAL APPEARANCE:

Nucleus — No marked central condensation has been visible during the 1951 or 1958 passages.

Coma — Coma seems to start forming 100 days before perihelion (mag 17 in 1958). It grows through perihelion and reached about 10^5 km dia in 1951 (mag 12).

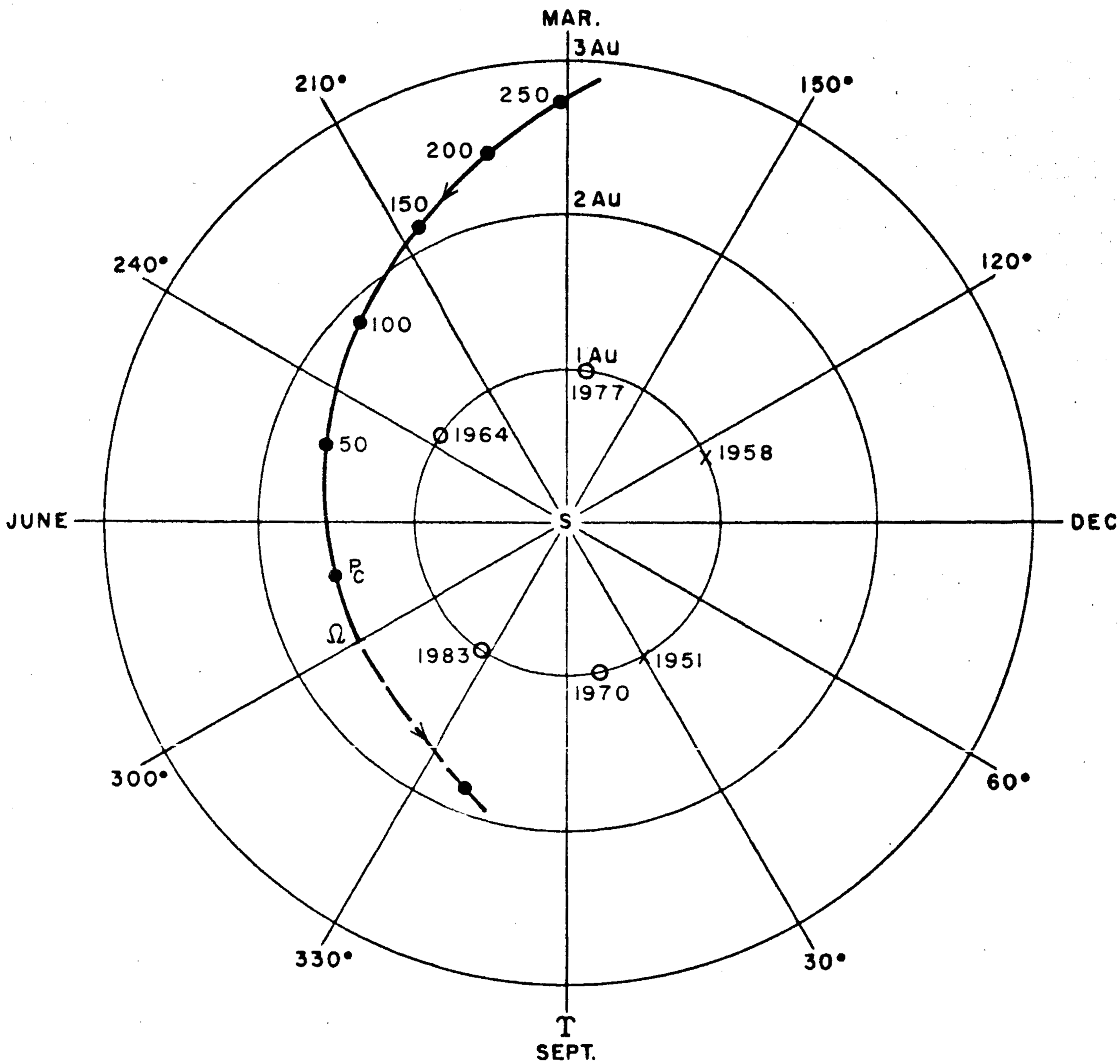
Tail — No significant tail is associated with this comet.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
155 after	18.8	2 AU	Poor	20 Jan 58	--	V. poor	180
183	19	2.3 AU	Good	20 Oct 51	12	Fair	235

GENERAL COMMENTS: Not a bright comet but it has been observed out to beyond 3 AU. No spectral data is available. The 1983 apparition will be the best for both recovery and observation and it will be fairly bright at perihelion. It may be worth considering for a mission prior to Halley's comet.

KOPFF



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PERIODIC COMET NEUJMIN I

HISTORICAL: Discovered just after perihelion in 1913 and recovered in 1931 after perihelion. Last observed in 1948 for about 200 days up to perihelion.

BRIGHTNESS: (See Section 2.4)

ORBITAL PARAMETERS: (1948)

Period (P)	= 17.9 yrs	Eccentricity (e)	= 0.774
Semi-major axis (a)	= 6.85 AU	Long. asc. node (Ω)	= 347.2°
Inclination (i)	= 15.1°	Arg. perihelion (ω)	= 346.7°

PHYSICAL APPEARANCE:

Nucleus Upper and lower limits of diameter calculated as 70 km and 10 km (1948). Mass estimated as 3×10^{17} gms. Asteroidal in appearance in 1913.

Coma Small faint coma mag 16 in 1948.

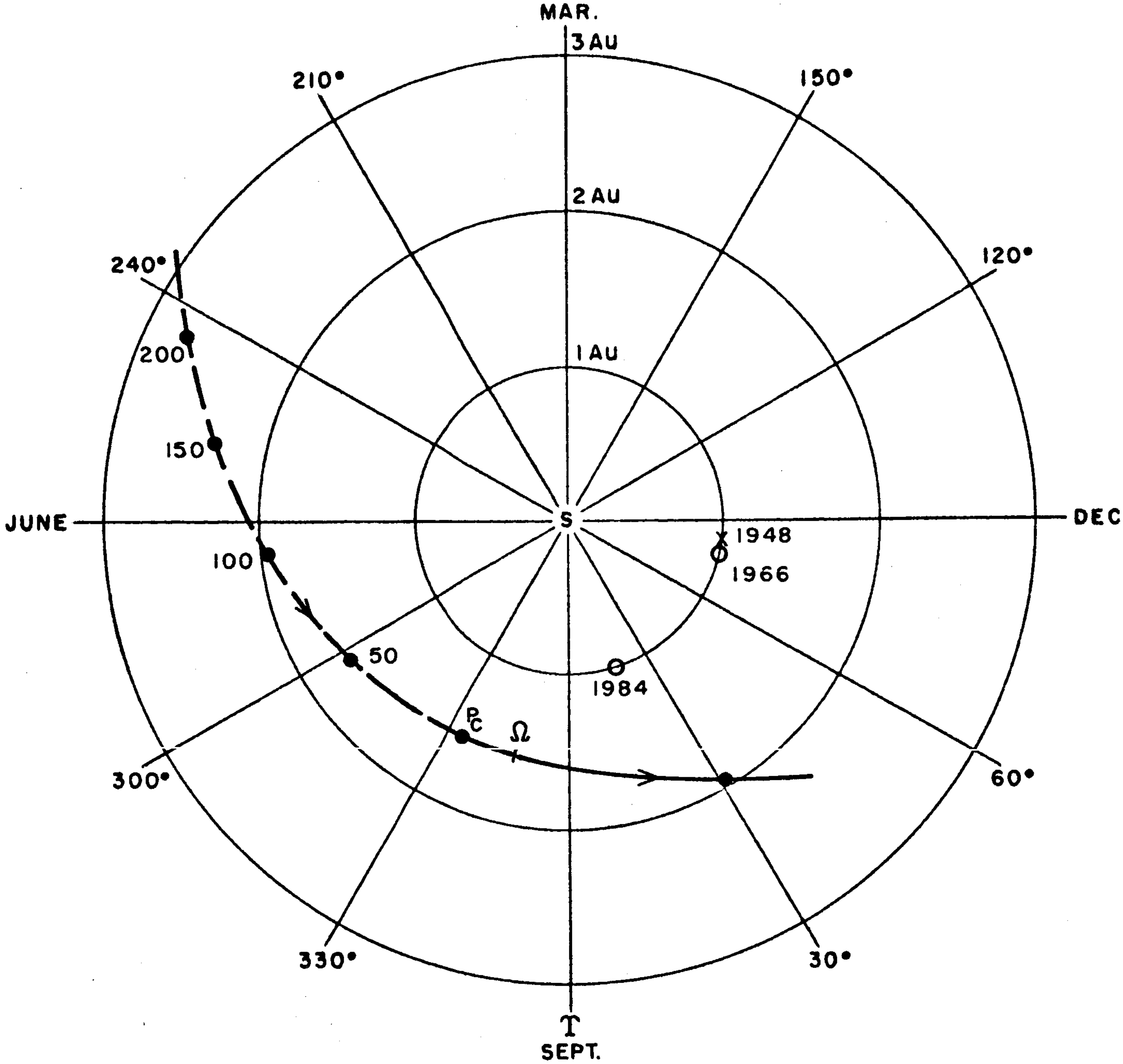
Tail Only a slight indication of a tail is associated with Neujmin I.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
200	20	3.2 AU	Good	15 Dec 48	16	Poor	200

GENERAL COMMENTS: It has been observed on its two passes since discovery but it is a faint and generally inactive comet. No spectral data exists. Observing conditions improve for 1966 and 1984 for recovery (200 days) although observation from the northern hemisphere may be difficult. It should be fairly well observed through perihelion particularly in 1984. It is of questionable value for an intercept mission.

NEUJMIN I



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PERIODIC COMET NEUJMIN 3

HISTORICAL: Discovered and observed for 5 weeks in 1929; it was not seen in 1940, but was recovered just before perihelion in 1951. It suffered a small perturbation in 1956 and is subject to occasional further perturbations by Jupiter.

BRIGHTNESS: (See Section 2.4)

$$m = 10.0 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1961)

Period (P)	= 10.57 yrs	Eccentricity (e)	= 0.591
Semi-major axis (a)	= 4.82 AU	Long. asc. node (Ω)	= 150.7°
Inclination (i)	= 3.86°	Arg. perihelion (ω)	= 147.6°

PHYSICAL APPEARANCE:

Nucleus — The nucleus has not been well defined in any observations.

Coma — Only a small faint round coma with little central condensation has been observed.

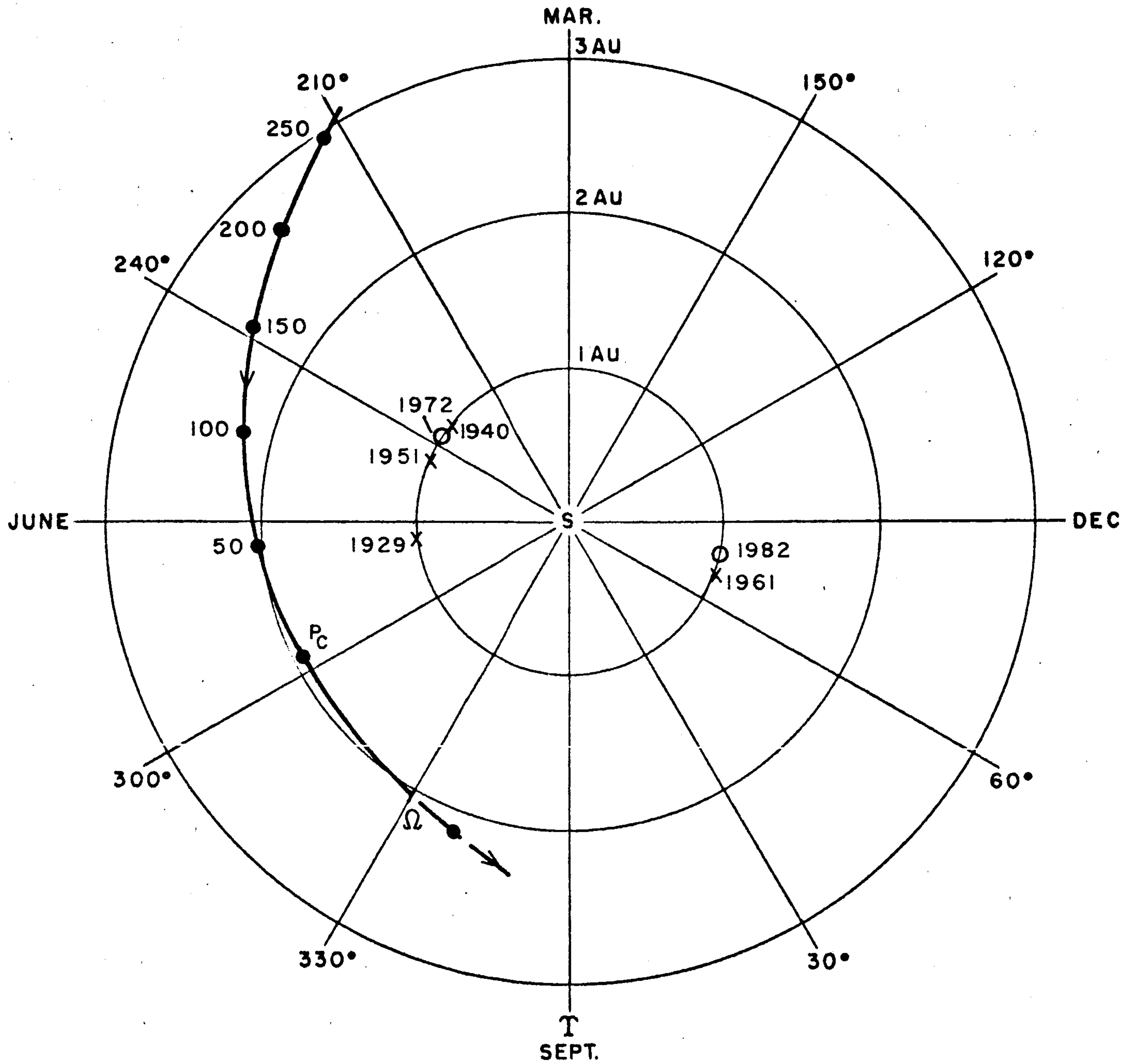
Tail — No trace of a tail has yet been detected.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
Not seen in	1961		Poor	2 Dec 61		Poor	
20	18.6	2.0 AU	Fair	28 May 51	18	Fair	180
Not seen in	1940		Fair	15 May 40		Fair	
45 after	18	2.05 AU	Discovered	28 Jun 29		Good	35

GENERAL COMMENTS: A very faint comet which although discovered over 30 years ago it has not been very well observed. Its orbit is becoming better known and earlier recoveries may now be possible. The 1972 apparition will be considerably better than that in 1982 but the comet will be faint at perihelion. It is probably not worth considering for a mission.

NEUJMIN 3



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PERIODIC COMET OTERMA

HISTORICAL: Discovered in 1943 and since observed every year and even throughout a whole orbit due to its low eccentricity. It will be perturbed by Jupiter during 1962/63 into an orbit entirely outside Jupiter with a period of 19.3 yrs.

BRIGHTNESS: (See Section 2.4)

$m = 9.5 + 10 \log r + 5 \log \Delta$. Observed magnitudes lie between 13 and 19 and variations are only due to distance.

ORBITAL PARAMETERS: (1960)

Period (P)	= 7.93 yrs	Eccentricity (e)	= 0.147
Semi-major axis (a)	= 3.98 AU	Long. asc. node (Ω)	= 154.9°
Inclination (i)	= 4.0°	Arg. perihelion (ω)	= 356.4°

PHYSICAL APPEARANCE:

Nucleus A strongly condensed almost stellar nucleus is always observed.

Coma A small diffuse coma surrounds the well condensed nucleus.

Tail A faint narrow tail is associated with Oterma.

RECENT RECOVERIES:

Observed each year.

GENERAL COMMENTS:

A faint "annual" comet which does not show the brightening of Schwassmann-Wachmann I. The present orbit perturbation reverses the change in 1937 after which it was observed. It is possible that it may not be bright enough to be seen in its new orbit. No polar chart has been included because of the much enlarged orbit which is being generated at present. It is not suitable for an intercept mission.

PERIODIC COMET PERRINE-MRKOS

HISTORICAL: First discovered in 1896 (Perrine) and rediscovered in 1955 (Mrkos). Suffered a large perturbation in 1959 due to its node lying near the orbit of Jupiter.

BRIGHTNESS: (See Section 2.4)

$$m = 9.0 + 15 \log r + 5 \log \Delta \text{ (not very accurate)}$$

ORBITAL PARAMETERS: (1962)

Period (P)	= 6.71 yrs	Eccentricity (e)	= 0.644
Semi-major axis (a)	= 3.56 AU	Long. asc. node (Ω)	= 240.3°
Inclination (i)	= 17.7°	Arg. perihelion (ω)	= 166.0°

PHYSICAL APPEARANCE:

Nucleus A fairly well condensed nucleus which is never quite stellar has been seen at both apparitions.

Coma A faint diffuse coma has been reported from photographic observations but visual sightings indicated a brightness some 5 magnitudes greater.

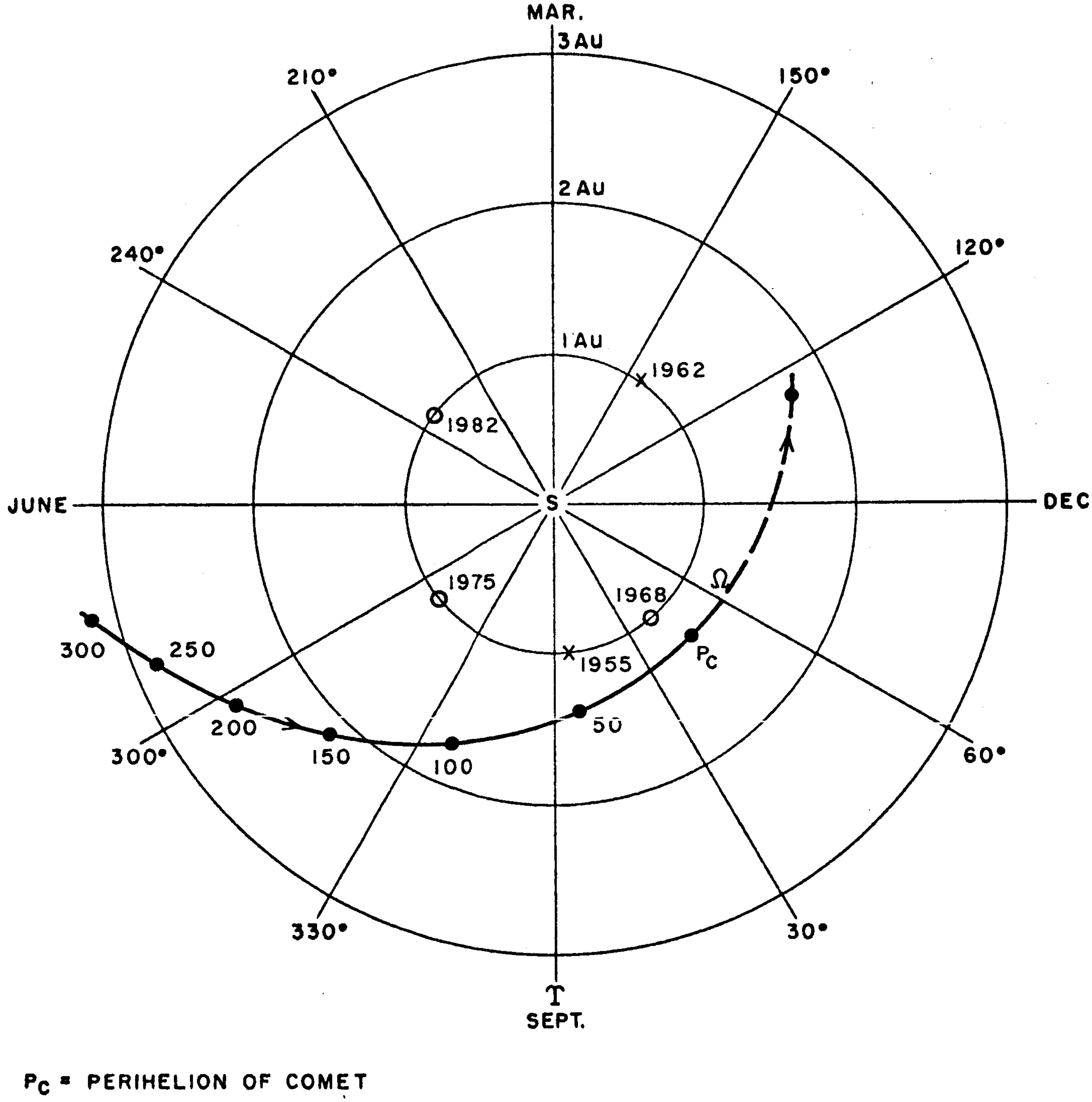
Tail A trace of a tail has been reported on both apparitions.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
150	19.8	2 AU	Fair	11 Feb 62	17.5	Fair	200
25 after	14	1.2 AU	Discovered	27 Sept 55	--	--	100

GENERAL COMMENTS: The 1955 rediscovery apparition indicated a fairly bright comet but it was faint in 1962 due in some measure to the relative position of the Earth. It was observed up to conjunction in April 1962 some 6 weeks after perihelion. The 1968 return promises to be quite good for recovery and very good for observation at perihelion (mag 10). It is certainly the best for this comet within the next 25 years and should be considered for a mission despite the fact that it is not a well known comet.

PERRINE-MRKOS



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PERIODIC COMET PONS-WINNECKE

HISTORICAL: Discovered in 1819 (Pons) and again in 1858 (Winnecke), it has been observed on 15 passages. It was not seen in 1957 due to poor observing conditions. Strong meteor showers were observed in 1916 after a perturbation brought it near to the Earth.

BRIGHTNESS: (See Section 2.4)

$$m = 12.5 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1964)

Period (P)	= 6.29 yrs	Eccentricity (e)	= 0.639
Semi-major axis (a)	= 3.41 AU	Long. asc. node (Ω)	= 92.8°
Inclination (i)	= 22.3°	Arg. perihelion (ω)	= 172°

PHYSICAL APPEARANCE:

Nucleus   Stellar nucleus which has appeared to be in a number of pieces. Diameter estimated as approx 1-2 km after a near Earth approach in 1927. Emission consists of a continuum with CH_2, CN and C_2 bands.

Coma   Fairly bright well developed coma is usual. The spectrum shows a continuum and a CN band stronger than the C emission. It has been observed 230 days before perihelion at 20 mag (1951).

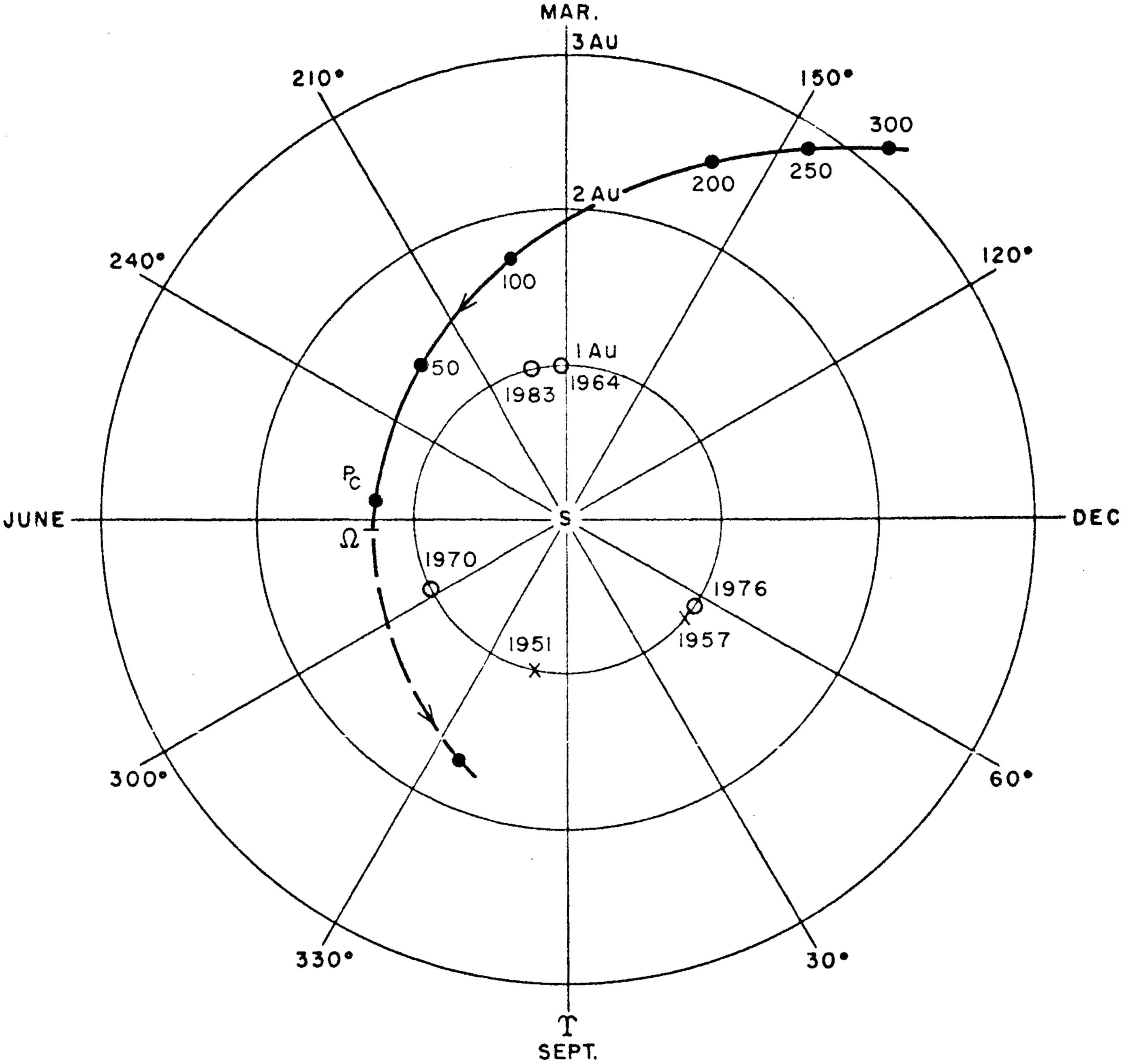
Tail   A short tail is associated with Pons-Winnecke.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
Not seen in	1957		Poor	23 Nov 57		Poor	
230	20	2.8 AU	Good	9 Sept 51	14	Good	280

GENERAL COMMENTS: A moderately bright comet which has been well observed over quite large arcs despite its large inclination. It is subject to perturbation by Jupiter which is gradually enlarging its orbit and period. The 1970 apparition promises to be the best when recovery and observation at perihelion will be good. This comet should be well worth considering for an intercept mission in 1970.

PONS-WINNECKE



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PERIODIC COMET REINMUTH I

HISTORICAL: Discovered in 1928 and also observed at its 1935, 1950 and 1958 returns. It suffered a perturbation in 1961 and the orbit shown is for the 1965 passage.

BRIGHTNESS: (See Section 2.4)

$$m = 10.6 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1958)

Period (P)	= 7.65 yrs	Eccentricity (e)	= 0.478
Semi-major axis (a)	= 3.88 AU	Long. asc. node (Ω)	= 123.5°
Inclination (i)	= 8.40°	Arg. perihelion (ω)	= 12.93°

PHYSICAL APPEARANCE:

Nucleus Almost stellar at distances greater than 2 AU and it remains well condensed through perihelion.

Coma Generally small faint coma mag 17 at perihelion in 1958.

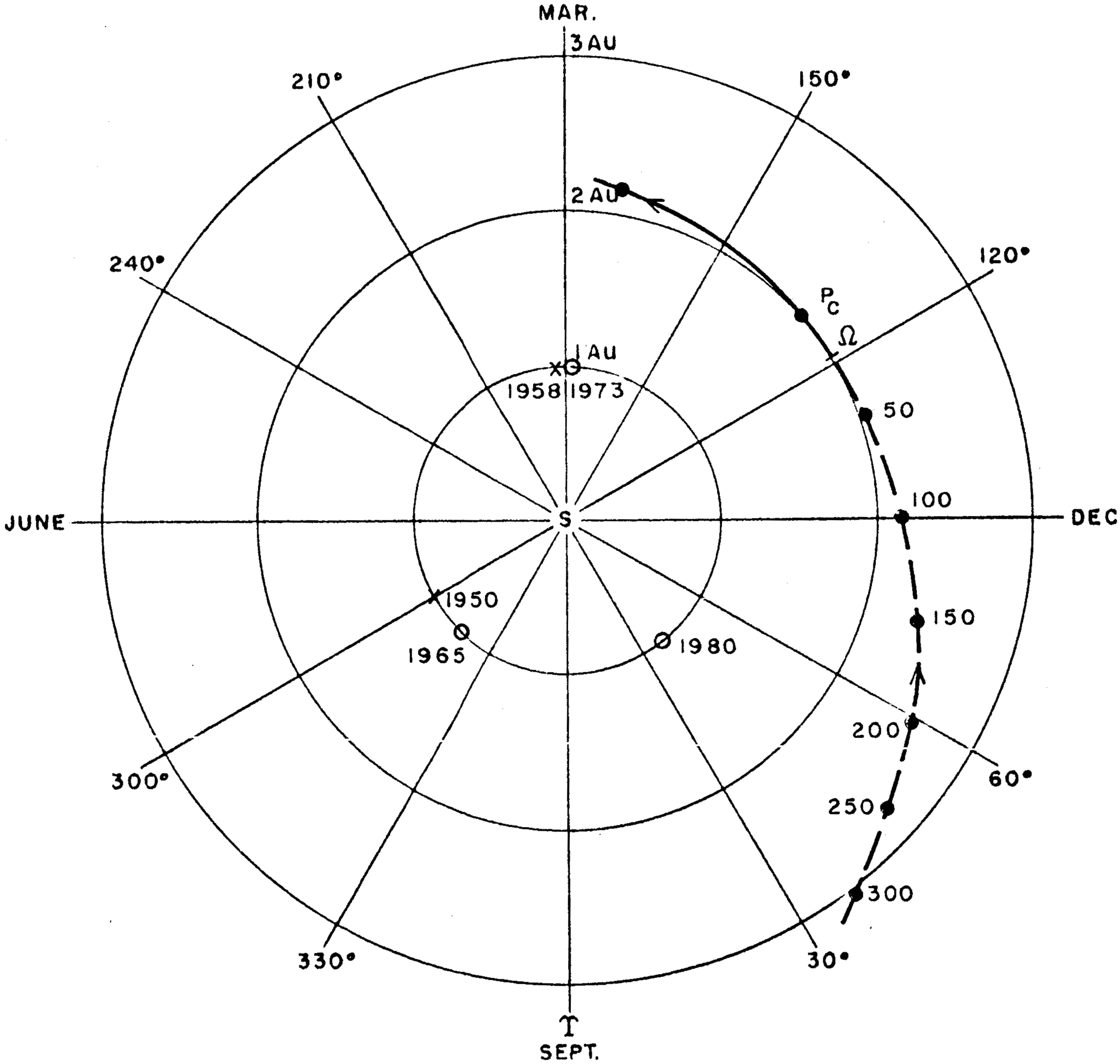
Tail Only a faint short tail has been observed with Reinmuth I.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
185	20	2.5 AU	Good	25 Mar 58	17	Good	225
254	18	2.9 AU	Good	21 Jul 50	--	V. Poor	100

GENERAL COMMENTS: A faint comet which is not well known physically. The 1973 apparition is probably the best in the period considered but is not good enough to make this comet suitable for an intercept mission.

REINMUTH I



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PERIODIC COMET REINMUTH 2

HISTORICAL: Discovered after perihelion in 1947 and again observed in 1954 and 1960. It is subject to only small perturbations by Jupiter.

BRIGHTNESS: (See Section 2.4)

ORBITAL PARAMETERS: (1960)

Period (P)	= 6.71 yrs	Eccentricity (e)	= 0.457
Semi-major axis (a)	= 3.56 AU	Long. asc. node (Ω)	= 296.17°
Inclination (i)	= 6.99°	Arg. perihelion (ω)	= 45.48°

PHYSICAL APPEARANCE:

Nucleus — Well condensed and defined through its apparition.

Coma — Only a small round coma which is well condensed.

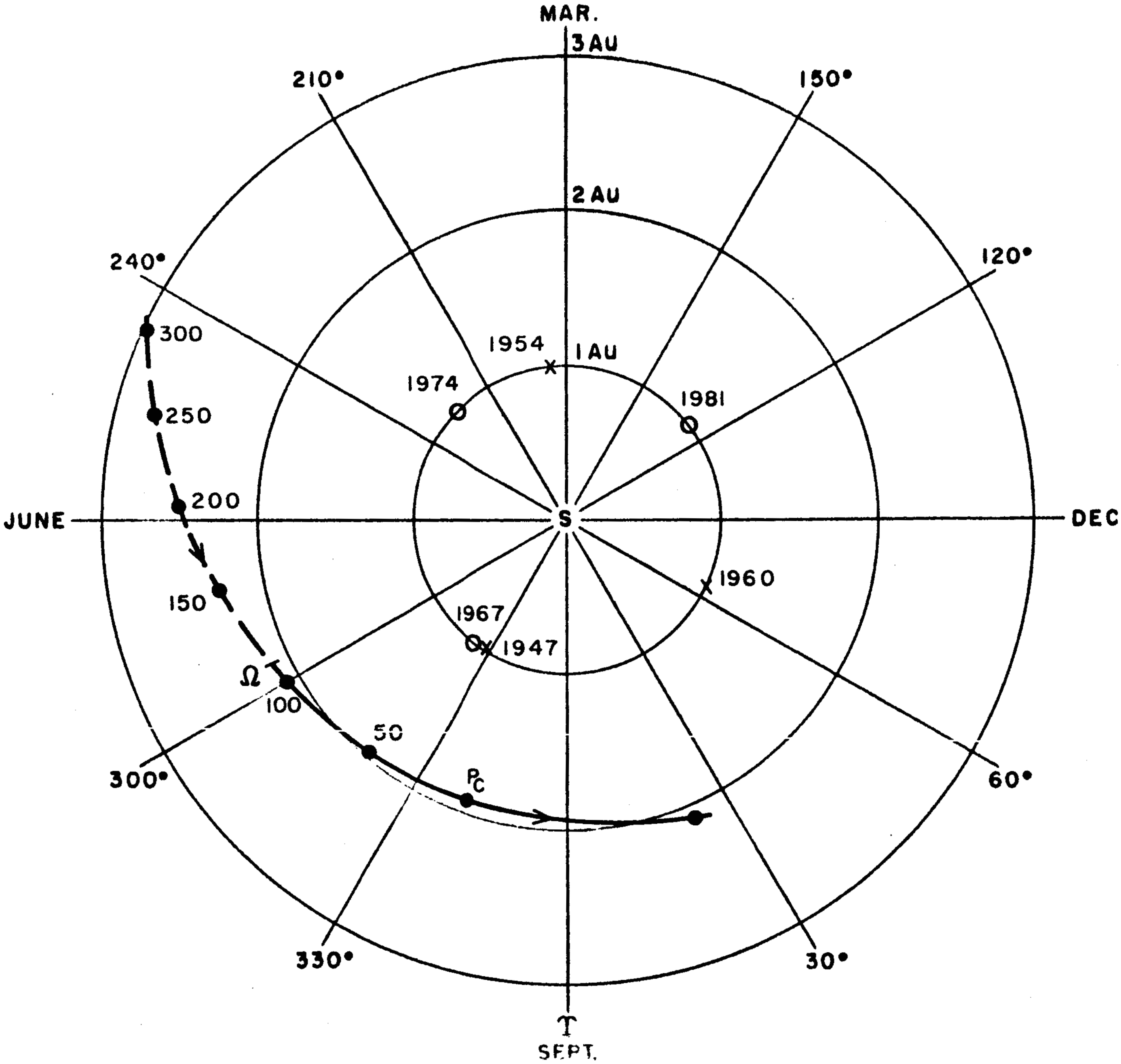
Tail — A faint trace of a tail has been detected.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
186	19.3	2.5 AU	Good	24 Nov 60	18	Fair	230
228	18	2.6 AU	Good	27 Mar 54	--	Poor	100
56 after	13.5	2 AU	Discovered	19 Aug 47	--		180

GENERAL COMMENTS: In 1954 it was in conjunction with the Sun shortly after recovery until after perihelion and was only observed beyond 150 days each side of perihelion. A faint comet which remains small and well condensed about the nucleus. It never approaches close to the Sun. Quite good recovery can be expected in 1967 with good observation at perihelion although it will not be very bright. It is not well known physically and probably not worth an intercept mission.

REINMUTH 2



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PERIODIC COMET SCHAUMASSE

HISTORICAL: Discovered in 1911, it has now been observed six times with a very good apparition in 1952.

BRIGHTNESS: (See Section 2.4)

$$m = 10 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1960)

Period (P)	= 8.18 yrs	Eccentricity (e)	= 0.705
Semi-major axis (a)	= 4.06 AU	Long. asc. node (Ω)	= 86.24°
Inclination (i)	= 12.0°	Arg. perihelion (ω)	= 51.95°

PHYSICAL APPEARANCE:

Nucleus Stellar in appearance at solar distances $>$ 2 AU and showing central condensation up to 3 or 4 months before perihelion. Thereafter it is usually quite diffuse and fuzzy. Spectrum includes a continuum with NH_2 and C_2 bands.

Coma Generally diffuse but round coma of moderate size (up to 10^4 km) after perihelion. Brightens after perihelion. The C_3 emission is stronger than CN and a continuum is evident.

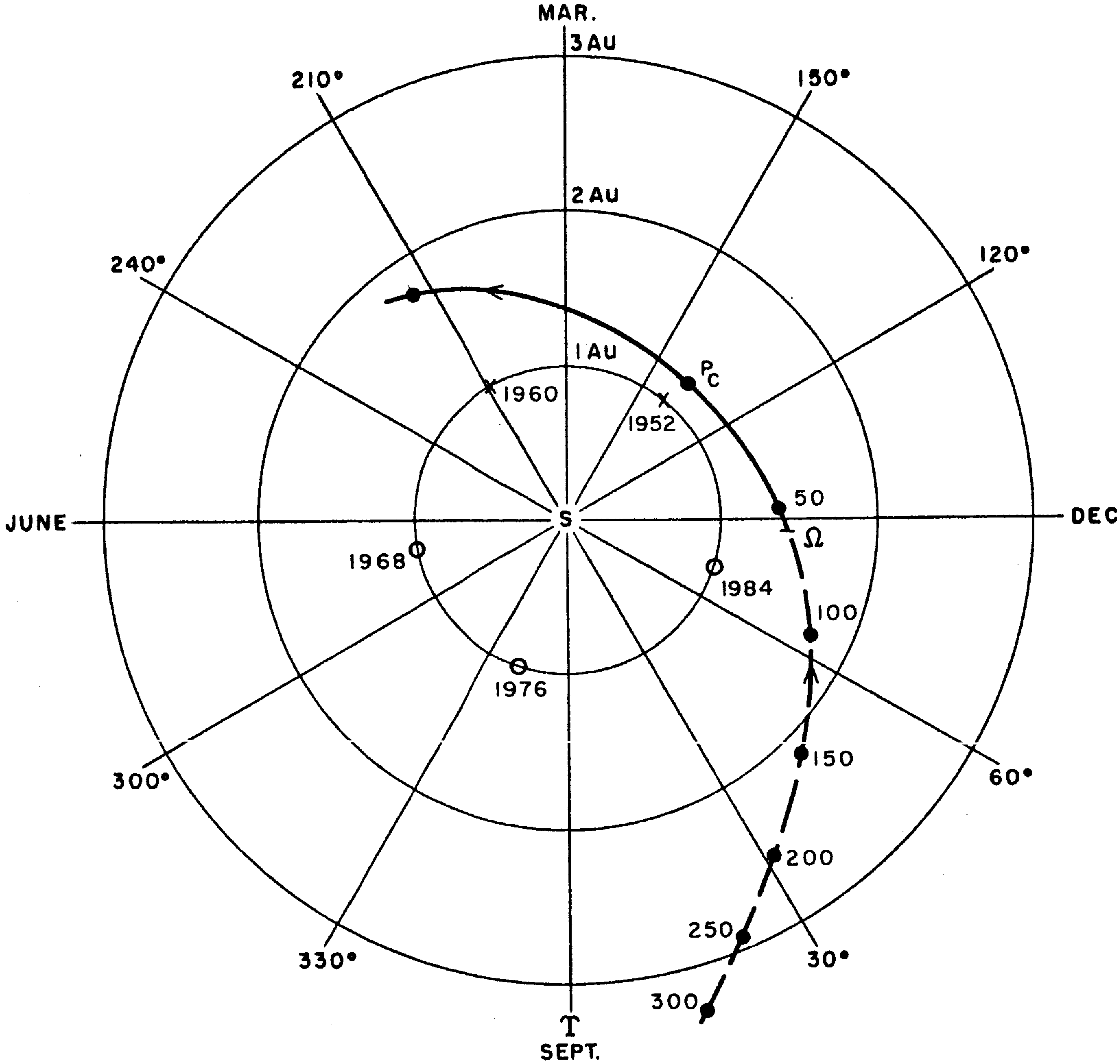
Tail A faint but broad tail has been seen with Schaumasse.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
200	20	2.5 AU	Good	18 Apr 60	13	Fair	270
140	19	2.1 AU	Good	10 Feb 52	8	V. Good	275

GENERAL COMMENTS: Schaumasse is a fairly bright but a diffuse comet. Considerable variation appears in its measured brightness but it is not certain that it is due to changes in the intrinsic brightness of the comet. In the 1952 apparition the Earth was almost in opposition when the comet was at perihelion which gave excellent observing conditions. The 1984 passage will be better than the others but the comet will be faint at perihelion. It is not recommended for a mission.

SCHAUMASSE



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PERIODIC COMET SCHWASSMANN-WACHMANN I

HISTORICAL: Discovered in 1925 and it has been observed at opposition every year since then. It has the smallest eccentricity of all comets and lies between orbits of Jupiter and Saturn. It is subject to perturbation by both these planets.

BRIGHTNESS: (See Section 2.4)

The magnitude at opposition is usually about 18 but it is subject to sudden increases (10.7 mag, Oct. 1959, 12.5 mag, Jan. 60) over a few days.

ORBITAL PARAMETERS: (1962)

Period (P)	= 16.1 yrs	Eccentricity (e)	= 0.132
Semi-major axis (a)	= 6.21 AU	Long. asc. node (Ω)	= 321.6°
Inclination (i)	= 9.5°	Arg. perihelion (ω)	= 355.8°

PHYSICAL APPEARANCE:

Nucleus A sharp and occasionally stellar nucleus is observed. It is active in forming halos which are generally uniform. Rapid changes in magnitude are observed. Only a solar continuum has been detected.

Coma A round diffuse coma is often detected but only a slight gaseous atmosphere is present. The diameter has been estimated as $\simeq 10^6$ km. The emission is restricted to a solar continuum.

Tail A faint tail is occasionally observed.

RECENT RECOVERIES:

Observable every year

GENERAL COMMENTS:

This is a faint comet which remains beyond the orbit of Jupiter. It has been observed every year and displays rapid and large changes in brightness. No polar plot has been included because of the almost circular nature of the orbit. It is not recommended for an early comet mission because of its large perihelion distance.

PERIODIC COMET SCHWASSMANN-WACHMANN 2

HISTORICAL: Discovered in 1928 and it has been seen at each return. Its orbit is almost coincident with Jupiter's near apogee and it is thus subject to occasional large perturbations. One of the smallest comet eccentricities.

BRIGHTNESS: (See Section 2.4)

$$m = 8.0 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1961)

Period (P)	= 6.53 yrs	Eccentricity (e)	= 0.382
Semi-major axis (a)	= 3.49 AU	Long. asc. node (Ω)	= 126.0°
Inclination (i)	= 3.72°	Arg. perihelion (ω)	= 357.74°

PHYSICAL APPEARANCE:

Nucleus A fairly well condensed nucleus is usually visible in a diffuse coma especially when near perihelion. It appears to be decaying in brightness by over 1 mag per decade. The emission is measured as solely a continuum indicating a high percentage of dust.

Coma Even at large distances (i.e., 3 AU) a diffuse coma is present. The coma remains somewhat fuzzy through perihelion and does not grow very large. It has been observed 400 days before perihelion at magnitude 20 (1960).

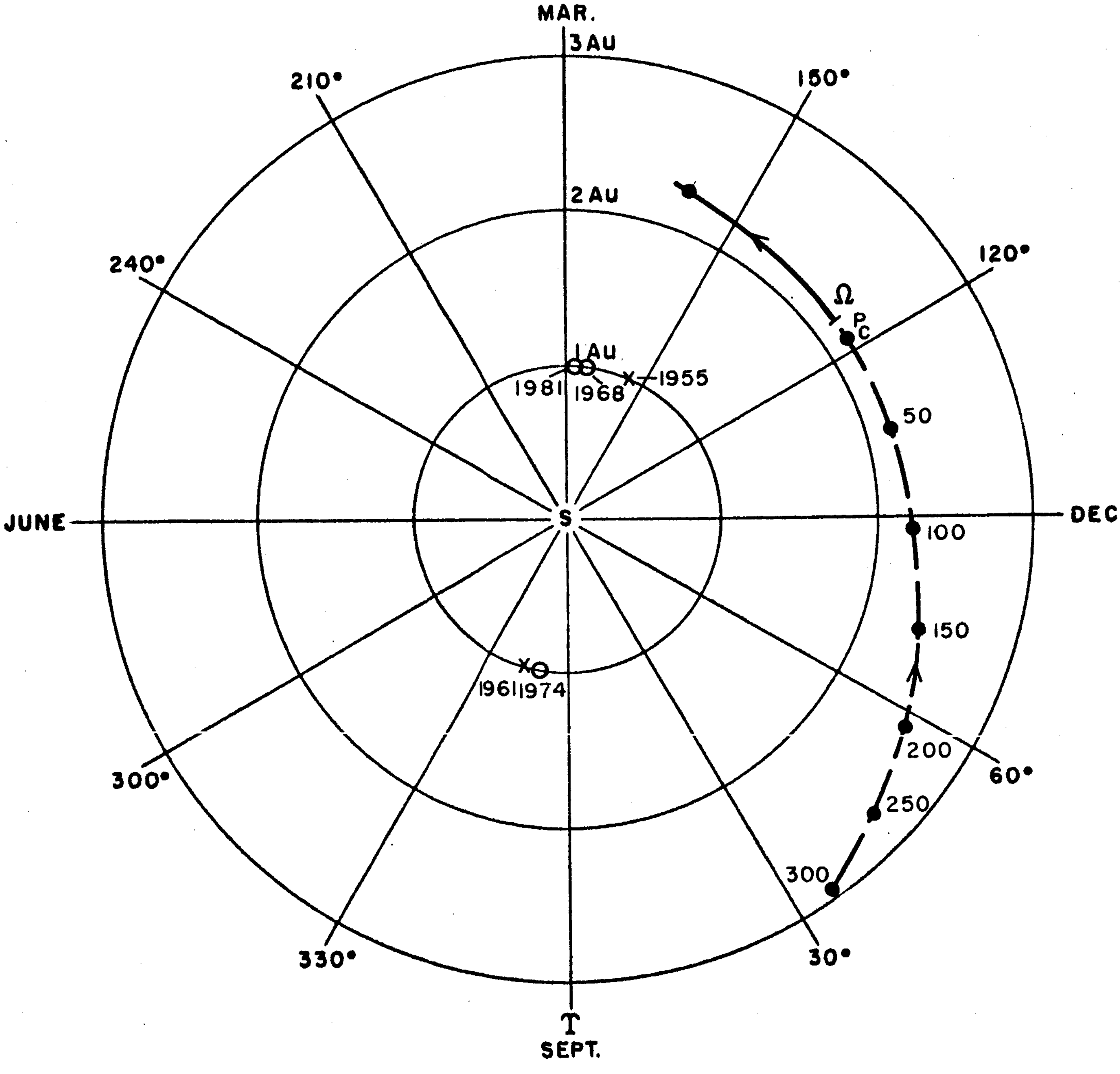
Tail A fairly long tail is observed particularly near perihelion.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
400	18	3 AU	Good	5 Sept 61	--	Poor	420
220	17	2.6 AU	Good	27 Feb 55	13	Good	310

GENERAL COMMENTS: The large perihelion distance and relatively small eccentricity make it potentially visible over very long arcs except when it is in conjunction with the Sun. It is not a bright object and requires the use of a large telescope to observe it. The 1968 and 1981 apparitions will be very similar offering quite good recovery. The comet may be as bright as mag 12 at these perihelia which makes it worth considering for a mission to a dusty comet.

SCHWASSMANN-WACHMANN 2



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PERIODIC COMET TEMPEL 2

HISTORICAL: It has made 13 observed appearances since discovery in 1873 and was well observed on its last apparition in 1962. Perturbations by Jupiter and Saturn (1953) slightly reduced the eccentricity and slightly increased the inclination.

BRIGHTNESS: (See Section 2.4)

$$m = 10.5 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1962)

Period (P)	= 5.26 yrs	Eccentricity (e)	= 0.550
Semi-major axis (a)	= 3.02 AU	Long. asc. node (Ω)	= 119.3°
Inclination (i)	= 12.5°	Arg. perihelion (ω)	= 191.0°

PHYSICAL APPEARANCE:

Nucleus Always stellar in appearance beyond 2 AU. A central condensation is usual near perihelion. The nucleus had a magnitude of 16 in 1962.

Coma The coma becomes apparent 150 days before perihelion and has reached a diameter of 5 x 10^4 km just after perihelion. It is generally diffuse of mag 10.6 (1946) 12 (1951) and 16 (1962) brightening after perihelion. CN is the strongest band in its spectrum.

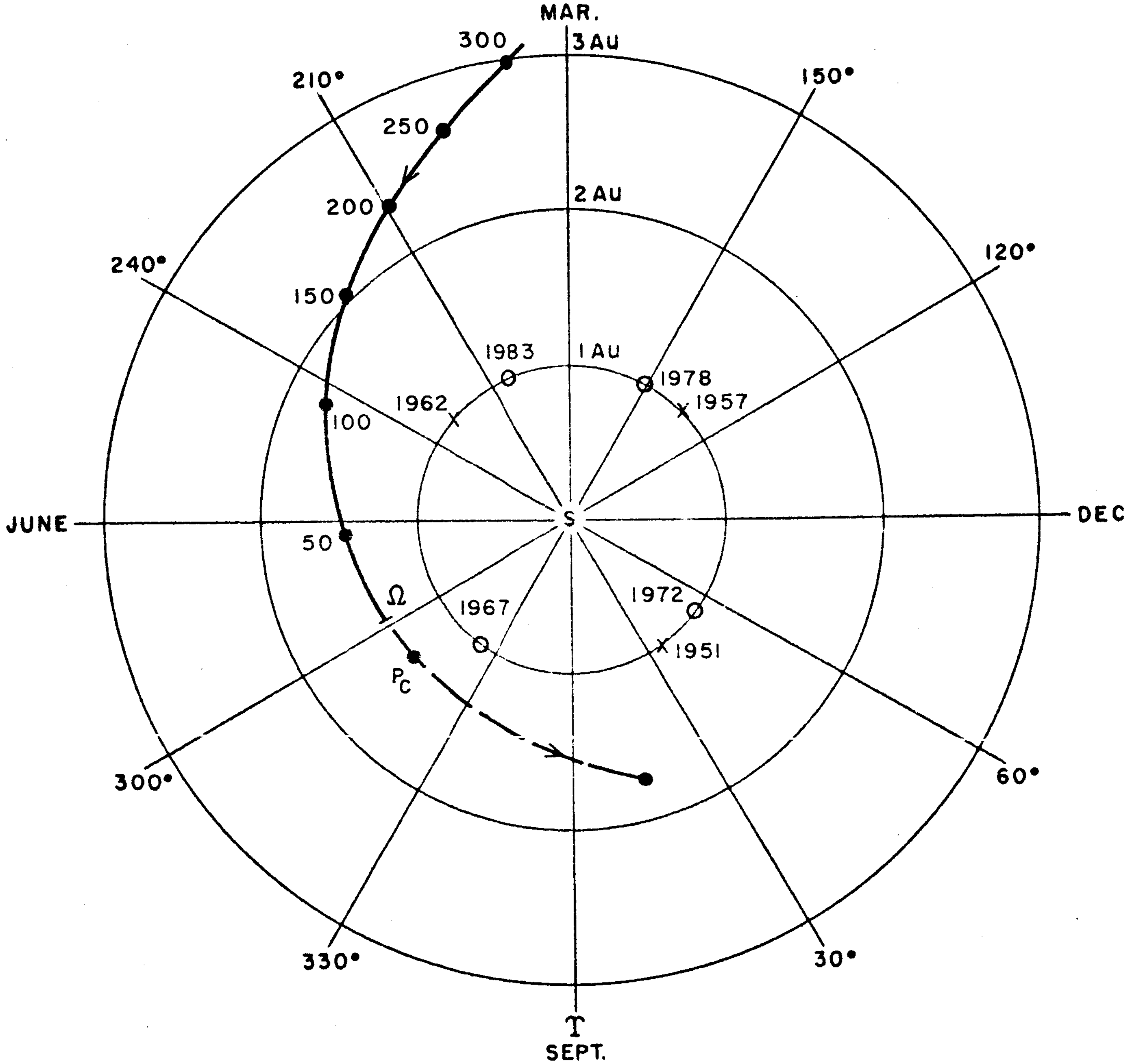
Tail Usually develops a tail near perihelion which persists for some 150 days.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
419	20.5	3.6 AU	Good	12 May 62	17.5	Fair	600
275	19	2.7 AU	Good	4 Feb 57	---	V. Poor	20
264	19.7	2.7 AU	Good	25 Oct 51	14	Fair	264

GENERAL COMMENTS: A fairly faint comet which has been recovered very early on its last three passes. The 1967 passage is by far the best in the next 25 years and good recovery and observation at perihelion can be expected. It may even be recovered about 400 days before perihelion before conjunction with the Sun. It should be considered as a target in 1967.

TEMPEL 2



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O = PREDICTED POSITIONS OF EARTH AT PERIHELION OF COMET (SEE SECT. 2·3)

PERIODIC COMET TUTTLE

HISTORICAL: Discovered in 1790 with the last apparition to be observed in 1939 being the eighth. It was too close to the Sun to be observed in 1953. It has been perturbed since it was last seen and the parameters below are adjusted by calculation. The Ursid permanent meteor shower is linked with Tuttle.

BRIGHTNESS: (See Section 2.4)

$$m = 9.0 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1953)

Period (P)	= 13.7 yrs	Eccentricity (e)	= 0.820
Semi-major axis (a)	= 5.74 AU	Long. asc. node (Ω)	= 269°
Inclination (i)	= 54.7°	Arg. perihelion (ω)	= 206°

PHYSICAL APPEARANCE:

Nucleus Observations in 1826 showed it to be very active and have an orange colored nucleus. A sharp well defined nucleus was observed in 1939.

Coma A coma greater than 10^4 km dia was detected in 1939 and was observed up to 60 days after perihelion.

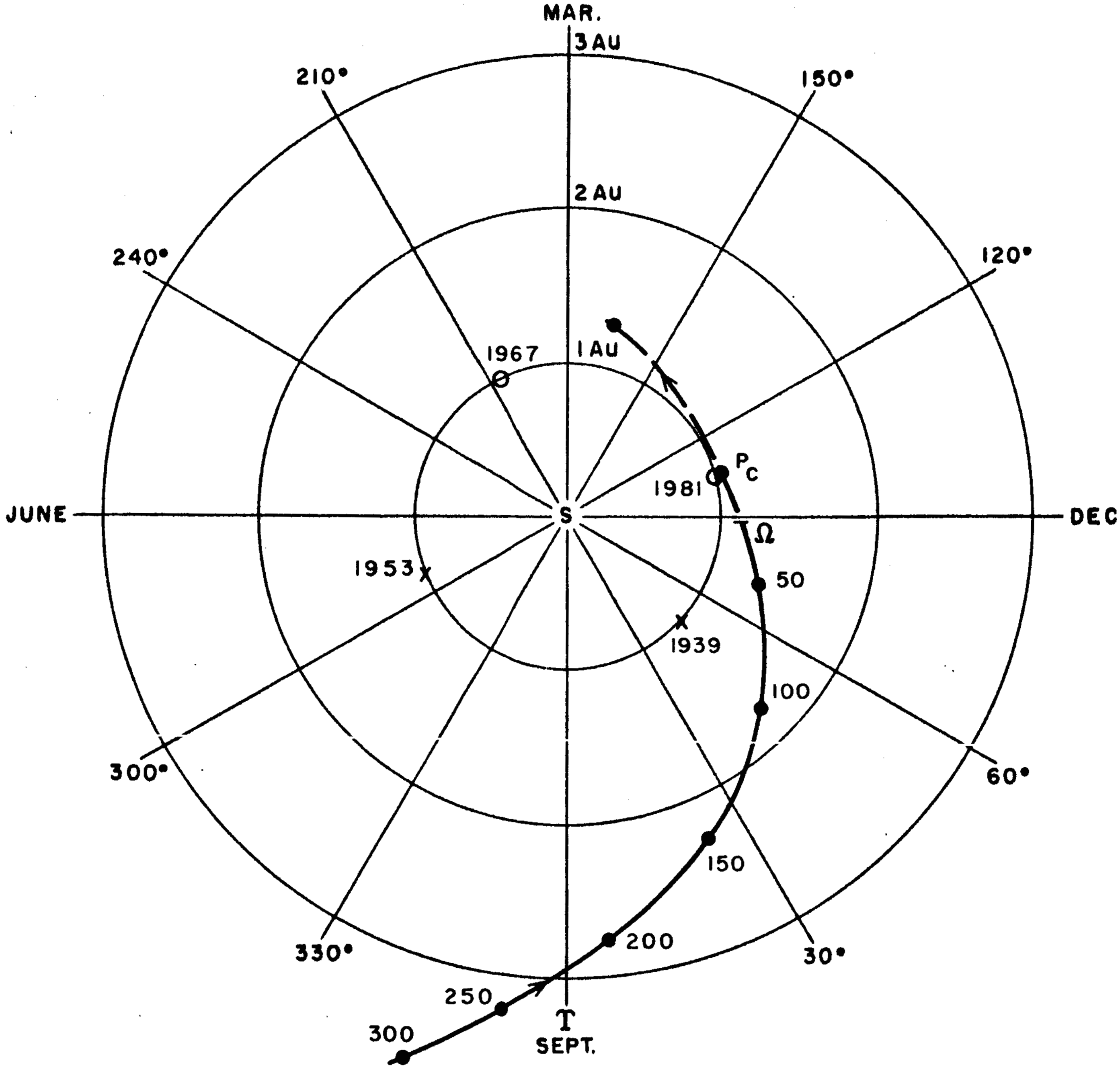
Tail No distinctive tail is associated with Tuttle.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
Not seen in 1953			Poor	12 Jul 53		Poor	
80	19	1.6 AU	Fair	10 Nov 39	17.5	Fair	210

GENERAL COMMENTS: It has a large inclination for a periodic comet which gives it a rapid motion as it passes down through the ecliptic one month before perihelion. The comet will be faint at perihelion in 1967 but the 1981 apparition should be excellent. This comet is not known in detail but should still be considered for a mission in 1981 because of its proximity to the Earth.

TUTTLE



P_C = PERIHELION OF COMET

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PERIODIC COMET TUTTLE-GIACOBINI-KRESAK

HISTORICAL: Observed in 1858 (Tuttle) 1907 (Giacobini) and rediscovered in 1951 (Kresak). It was unfavorably situated in 1956 and not observed. Recovery in 1962 was the first anticipated sighting of its return when it was within 1° of the predicted position.

BRIGHTNESS: (See Section 2.4)

$$m = 11.7 + 15 \log r + 5 \log \Delta \text{ (not very accurate)}$$

ORBITAL PARAMETERS: (1962)

Period (P)	= 5.49 yrs	Eccentricity (e)	= 0.639
Semi-major axis (a)	= 3.11 AU	Long. asc. node (Ω)	= 165.6°
Inclination (i)	= 13.8°	Arg. perihelion (ω)	= 38.0°

PHYSICAL APPEARANCE:

Nucleus Generally a strongly condensed nucleus: Mag 13.5 at perihelion in 1951 and mag 16 in 1962.

Coma A fairly large coma has been observed. It has reached 10^5 km dia 50 days after perihelion. The total brightness has not exceeded 10.5. No spectroscopic data is available.

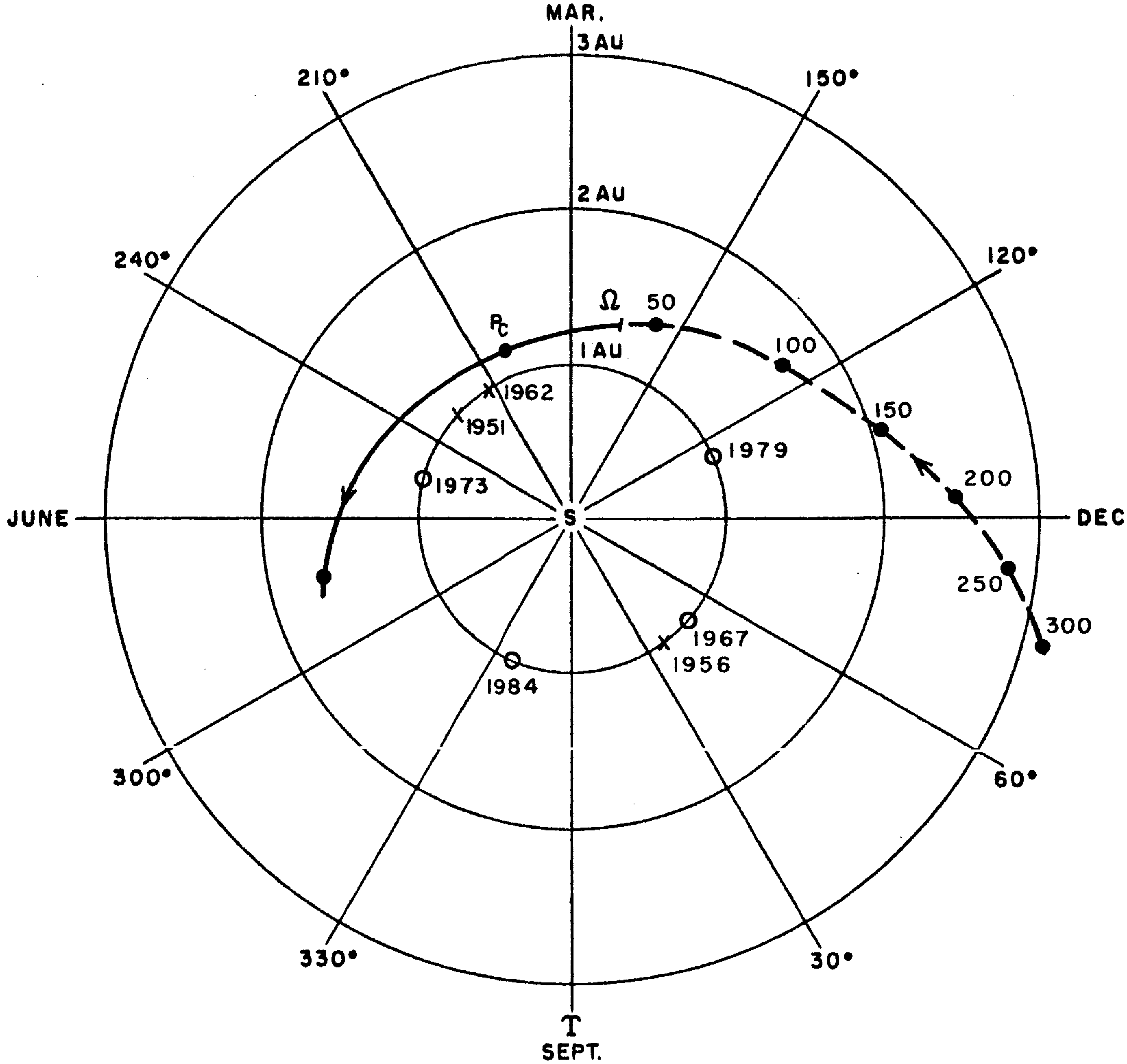
Tail No significant tail is associated with this comet.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
90	19	1.6 AU	Good	29 Apr 62	11	Good	190
Not seen in	1956		Poor	31 Oct 56		Poor	
15	10.5	1.15 AU	Good	9 May 51	10.5	Good	101

GENERAL COMMENTS: It is not a very bright comet and it is not very well known physically although reasonable faith can now be placed in the orbital parameters. The 1973 apparition will be the best within the next 25 years for both recovery and observation through perihelion. Although it will not be as bright at perihelion as in 1962 it is still probably worth considering for a mission.

TUTTLE-GIACOBINI-KRESAK



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PERIODIC COMET VAISALA I

HISTORICAL: Discovered in 1939, it was very briefly observed in 1949 and again seen in 1960. Its node is near the orbit of Jupiter and it will suffer perturbations over the 25 year period considered. Its period will be increased.

BRIGHTNESS: (See Section 2.4)

ORBITAL PARAMETERS: (1960)

Period (P)	= 10.5 yrs	Eccentricity (e)	= 0.636
Semi-major axis (a)	= 4.78 AU	Long. asc. node (Ω)	= 135.4°
Inclination (i)	= 11.3°	Arg. perihelion (ω)	= 44.4°

PHYSICAL APPEARANCE:

Nucleus A stellar nucleus was observed up to about 50 days before perihelion in 1960. It then remained very well condensed and defined through perihelion.

Coma Only a small diffuse coma has been observed and only near to perihelion.

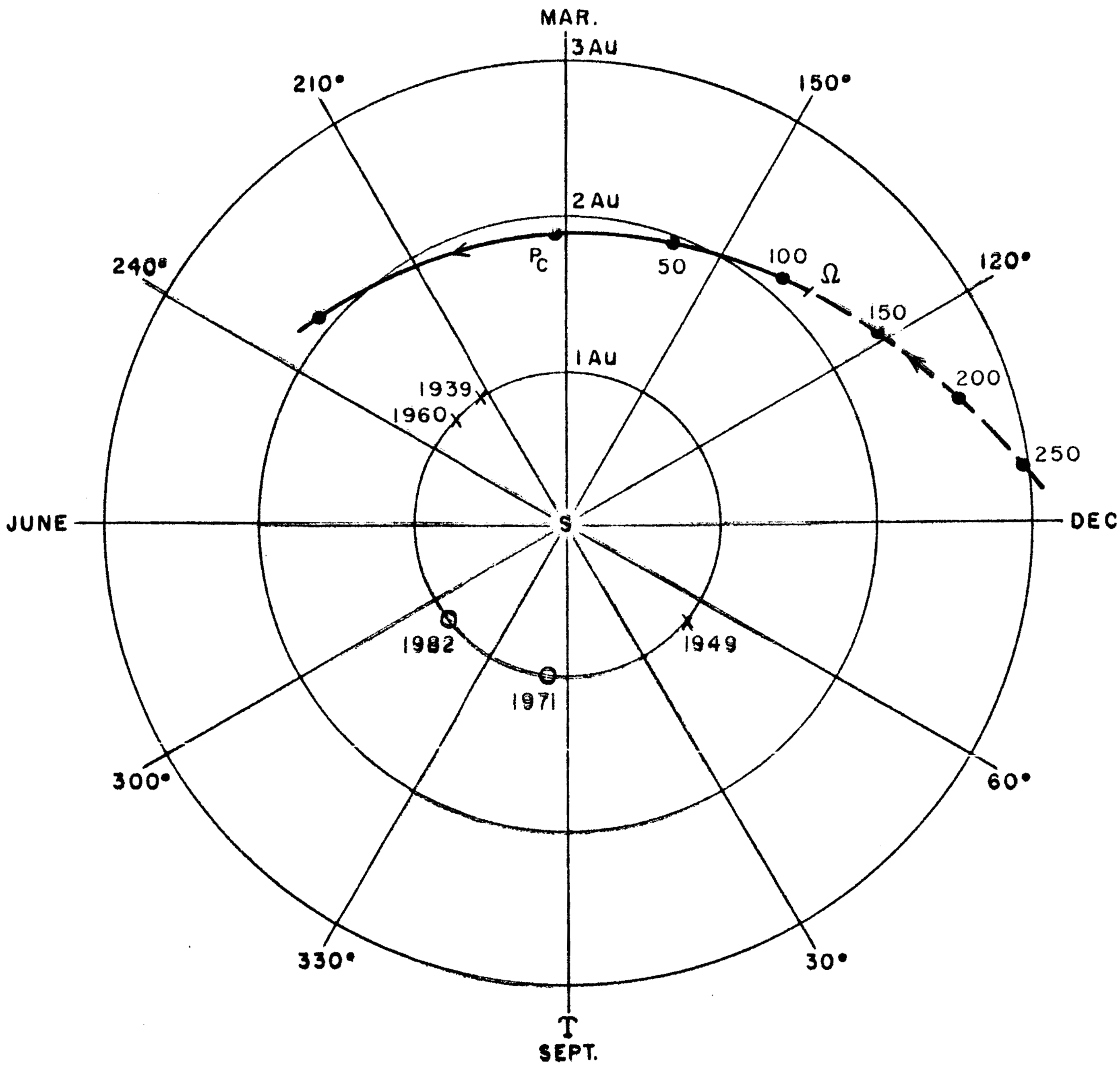
Tail A faint, short but fairly broad tail was observed in 1960.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
180	19.5	2.6 AU	Good	10 May 60	17	Good	230
30 after	18	1.8 AU	Poor	11 Nov 49	--	Poor	1 obs.only
90	16	2 AU	Discovered	26 Apr 39	--	Good	80

GENERAL COMMENTS: Vaisala I is a faint comet which approaches to within 0.7 AU of the Earth's orbit. The only prolonged observation of it since it was discovered was in 1960. Although relatively early recovery will be possible for both the 1971 and 1982 apparitions, the comet will not be visible at perihelion. Vaisala I is therefore not a suitable target for an intercept mission before 1985.

VAISALA I



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PERIODIC COMET WHIPPLE

HISTORICAL: Discovered in 1933 and observed in 1941, 1948, 1955 and 1963. It is subject to perturbation by Jupiter because the descending node lies almost on the orbit of Jupiter. This will not be serious before the 1978 apparition.

BRIGHTNESS: (See Section 2.4)

$$m = 10.5 + 10 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1963)

Period (P)	= 7.46 yrs	Eccentricity (e)	= 0.356
Semi-major axis (a)	= 3.80 AU	Long. asc. node (Ω)	= 188.5°
Inclination (i)	= 10.2°	Arg. perihelion (ω)	= 190.4°

PHYSICAL APPEARANCE:

Nucleus Almost stellar beyond 150 days from perihelion and remains fairly well condensed. It appears to be decaying in brightness by about a magnitude per decade.

Coma A large quite well defined coma through perihelion which in 1942 was found to be brighter in blue than in red.

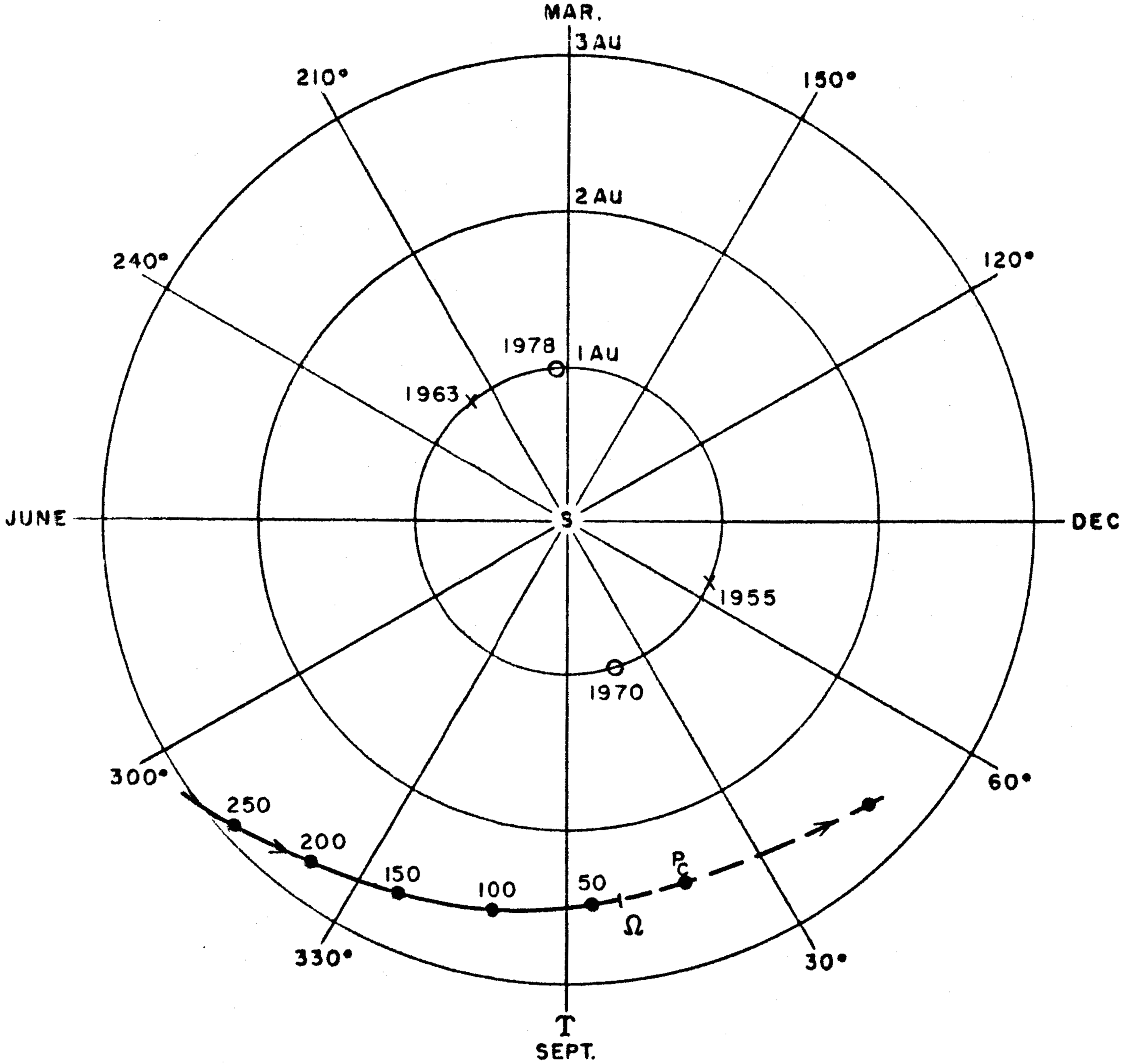
Tail It often displays a definite tail near perihelion which can be quite long. In 1942 the coloration was the reverse of the coma, i.e., brighter in red.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
310	20	3.1 AU	Good	29 Apr 63	--	Poor	?
190	18	2.7 AU	Good	29 Nov 55	16	Good	250

GENERAL COMMENTS: A fairly faint comet which does not brighten very much due to its large perihelion distance. It went into conjunction with the Sun before perihelion in 1963. The apparition in 1970 will offer about 200 days recovery and will be the best for observation through perihelion. However the large perihelion distance and the faintness of the comet make it unsuitable for an early intercept mission.

WHIPPLE



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PERIODIC COMET WIRTANEN

HISTORICAL: Discovered in 1947 after perihelion. Recovered in 1954 again after perihelion and observed again in 1961. It passes fairly close to the orbit of Jupiter which means it is liable to perturbation.

BRIGHTNESS: (See Section 2.4)

ORBITAL PARAMETERS: (1960)

Period (P)	= 6.67 yrs	Eccentricity (e)	= 0.543
Semi-major axis (a)	= 3.54 AU	Long. asc. node (Ω)	= 86.5°
Inclination (i)	= 13.4°	Arg. perihelion (ω)	= 343.5°

PHYSICAL APPEARANCE:

Nucleus — No defined nucleus or condensation has been seen with the limited observations up to the present.

Coma — A very diffuse coma.

Tail — No tail has been detected with the limited observations.

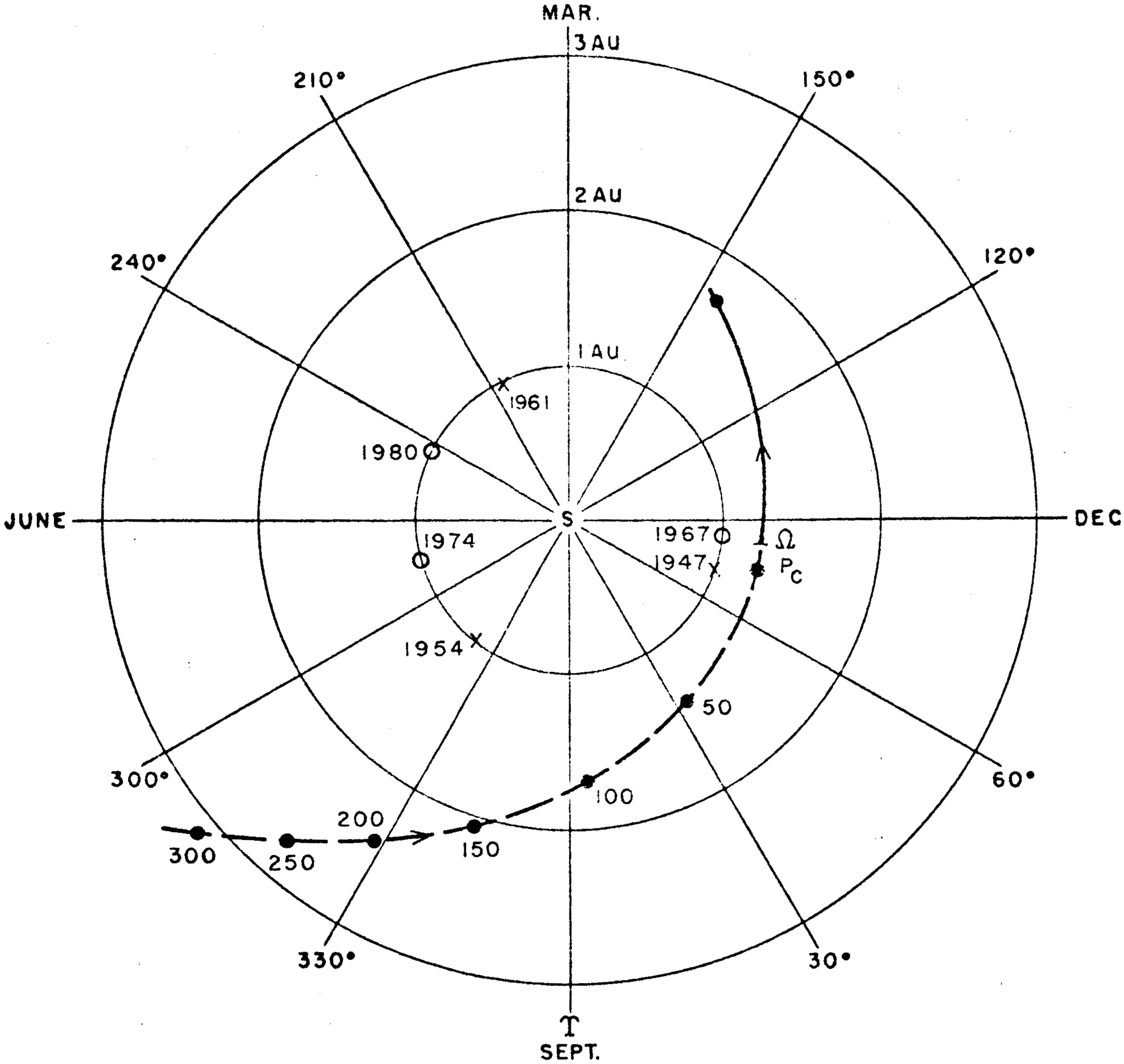
RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
156	20.8	2.2 AU	Good	15 Apr 61	--	Poor	110
50 after	18	1.8 AU	Poor	13 Aug 54	--	Fair	20
50 after	16	1.8 AU	Discovered	2 Dec 47	--		100

GENERAL COMMENTS: Wirtanen is a faint diffuse comet but its parameters are quite well established. It has only been observed 50 days either side of perihelion. The only good apparition will be in 1967 which is the next perihelion. Not enough is known about the comet to consider it for a mission in 1967.

Note: Periodic comet Wirtanen (1947 XII, 1954 XI, 1960 m) should not be confused with the parabolic comets also discovered by Wirtanen (1947 VI, 1947 VIII, 1949 I, 1957 VI).

WIRTANEN



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PERIODIC COMET WOLF

HISTORICAL: Discovered in 1884 and observed 10 times since then. It is a very faint highly inclined comet. It was seriously perturbed by Jupiter before discovery and is now being gradually pushed forward in its orbit, reducing the perihelion distance but increasing the eccentricity.

BRIGHTNESS: (See Section 2.4)

ORBITAL PARAMETERS: (1960)

Period (P)	= 8.43 yrs	Eccentricity (e)	= 0.395
Semi-major axis (a)	= 4.14 AU	Long. asc. node (Ω)	= 203.9°
Inclination (i)	= 27.3°	Arg. perihelion (ω)	= 161.1°

PHYSICAL APPEARANCE:

Nucleus An almost stellar nucleus is evident more than 200 days from perihelion. It becomes more diffuse near perihelion. Upper limit diameter calculated as 38 km.

Coma A faint very diffuse coma.

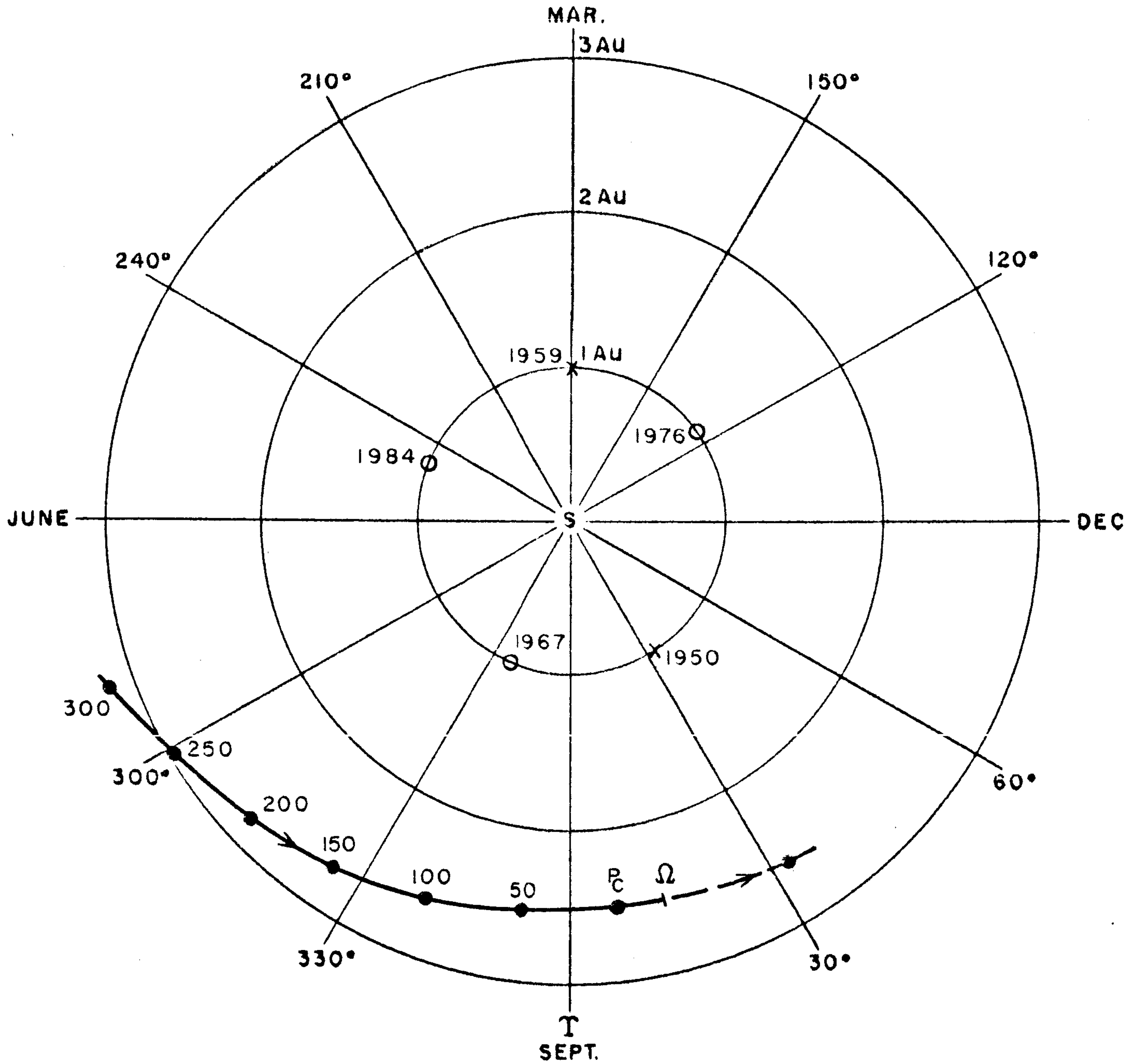
Tail No clear indication of a tail has been observed.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
275	20.5	3 AU	Good	21 Mar 59	--	Poor	60
75 after	19.5	1.2 AU	Fair	23 Oct 50	--	Good	10

GENERAL COMMENTS: Wolf is an extremely faint comet although its orbit is well established. The earliest recovery was in 1958 but it was only observed for a few months before it went into conjunction with the Sun. The next apparition in 1967 will be the best in the period up to 1985 but it will remain very faint. This, coupled with its large perihelion distance, make it unattractive for an intercept mission.

WOLF



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PERIODIC COMET WOLF-HARRINGTON

HISTORICAL: First seen in 1924 for one month only (Wolf) and rediscovered in 1951 (Harrington). It has since been seen in 1958. Recovery in 1958 was very near to the expected position. A slight perturbation in 1960 has been included in elements given below.

BRIGHTNESS: (See Section 2.4)

$$m = 10.8 + 15 \log r + 5 \log \Delta$$

ORBITAL PARAMETERS: (1964)

Period (P)	= 6.53 yrs	Eccentricity (e)	= 0.54
Semi-major axis (a)	= 3.49 AU	Long. asc. node (Ω)	= 254°
Inclination (i)	= 18.5°	Arg. perihelion (ω)	= 187°

PHYSICAL APPEARANCE:

Nucleus Well condensed, being almost stellar beyond 2 AU, and remaining condensed through the apparition.

Coma Develops a coma which was maximum in brightness 100 days before perihelion in 1952 (13 mag). Only a trace of coma after perihelion (1958).

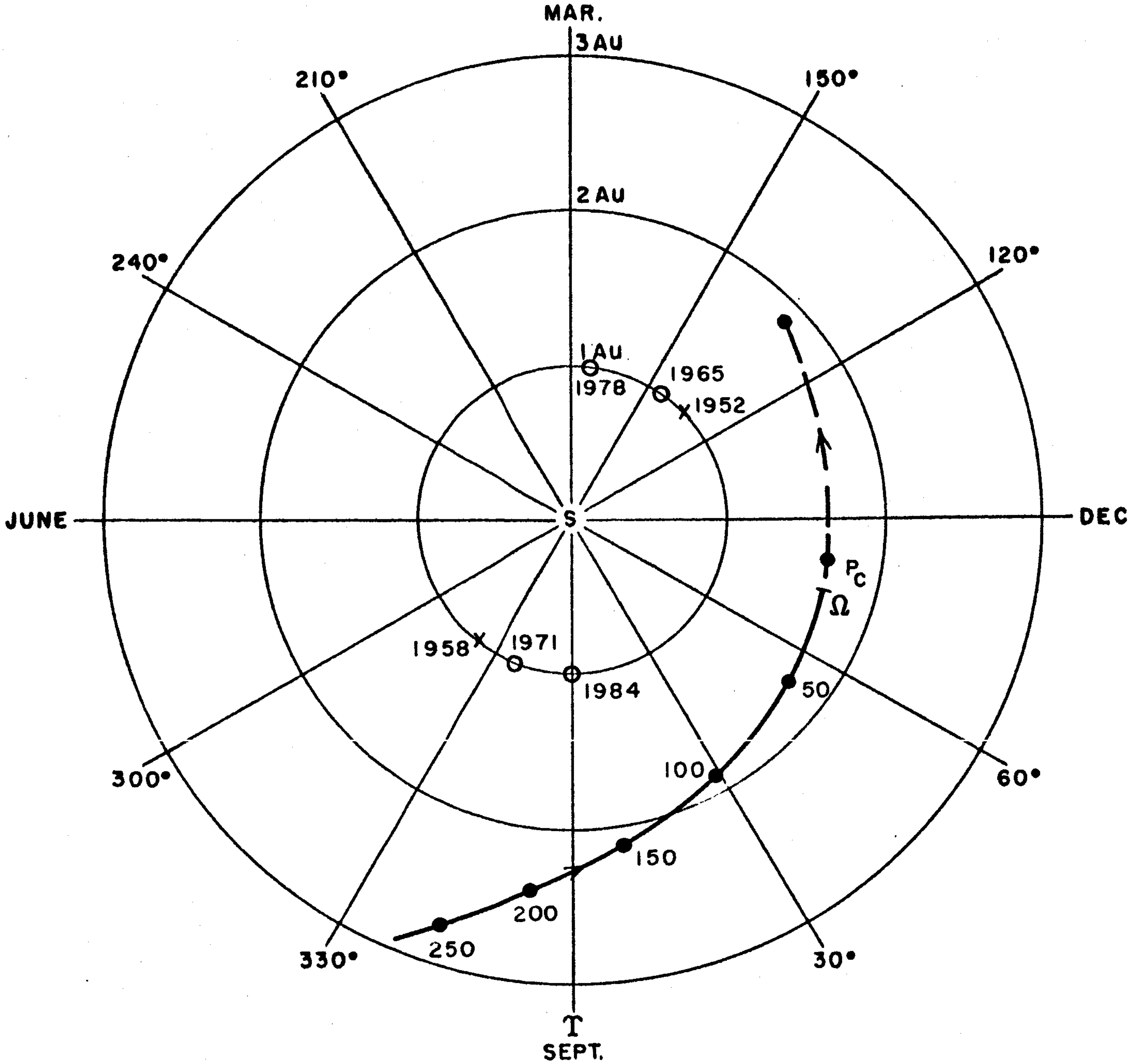
Tail Showed fairly large fan shaped tail which persisted out to 2.5 AU in 1958. Also displayed a tail in 1952.

RECENT RECOVERIES:

RECOVERY				PERIHELION			Total Observed Arc (days)
Days before Perihelion	Mag.	Solar Distance	Sighting Conds.	Date	Mag.	Sighting Conds.	
273	20	3 AU	Fair	11 Aug 58	17	Poor	250
122	16	2 AU	Good	4 Feb 52	13	Fair	210

GENERAL COMMENTS: A fairly faint comet for which no spectral data is available. It was in conjunction with the Sun from 30 days after recovery until perihelion in 1958. Every other apparition is reasonably good for recovery and observation at perihelion. Maximum recovery time is expected to be about 250 days before perihelion. However none of its predicted apparitions are expected to be well suited to an intercept mission.

WOLF-HARRINGTON



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